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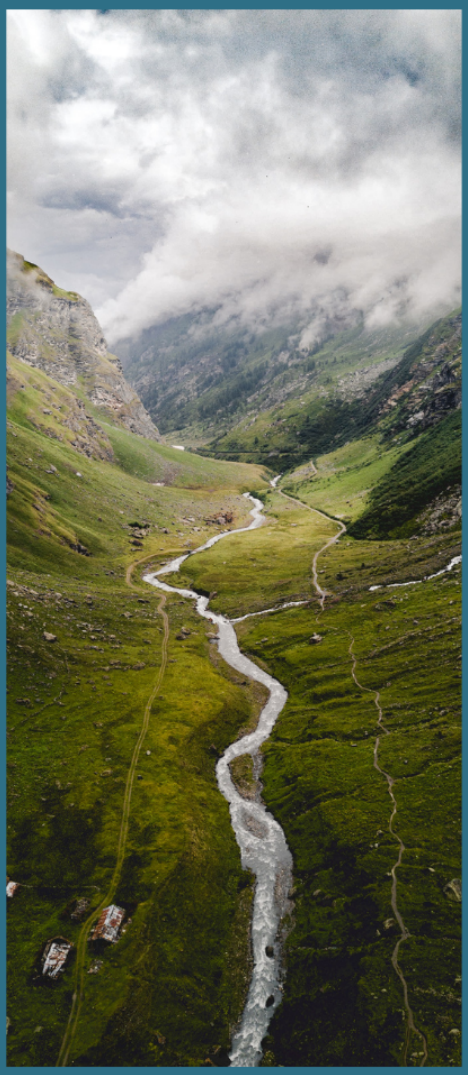

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Our Doctorsahib

It was in the nineteen-sixties that I began writing in Marathi on our common birds. The series was published by ''Kesari'', the daily founded by Lokmanya Tilak. These bird sketches written in simple language became popular and I was advised to compile them in a book. My friends suggested that the book should be released by Dr Salim Ali. With trepidation I wrote to him enclosing a copy of the Marathi book and asking whether it will be possible for him to travel to Pune for the release of the book. To my surprise he actually said, ''Yes!'' Obviously he must have learnt about the tone and flavour of the book from some of his colleagues who understood Marathi. The book was duly released in a simple ceremony held in the auditorium of the Maharashtra Association for the Cultivation of Science. He was delighted to meet some of his old associates from Pune, all of whom were members of the once flourishing Natural History Club. So began my long and fruitful association with the ace bird man of India.

Later during one of my frequent visits to BNHS in Mumbai, I learnt that he was keen to visit Sinhgad fort near Pune. We organised his visit, staying overnight in the bungalow where the famous meeting between Lokmanya Tilak and Mahatma Gandhi had taken place in he early years of twentieth century. The Pune birdwatchers had a field day roaming all day with him looking at larks and pipits, an occasional kestrel and a pair of crested serpent eagle whose calls reverberated in the valleys around the fort. He was amazed to see a number of long-billed vultues roosting on the vertical cliffs of the fort. Our movements disturbed the afternoon siesta of a great horned owl who expressed his displeasure by disappearing over the cliff without a whirr.

In the seventies I was the secretary of the Pune branch of World Wildlife Fund-India. Some of us birdwatchers then were trying to persuade the Forest Department to declare a protected area for birds along a one kilometre stretch of the rivers Mula and Mutha on the eastern end of the city. Dr F. Wadia whose family held a lease from the government over this landwas quite amenable to allow us to use the land for the purpose of creating a bird ''sanctuary''. this stretch of the rivers dotted with rocky outcrops forming shallow pools was much favoured by birds. On a morning stroll along the rivers one could easily count 50 species of birds in water as well as on the surrounding uplands. In winter huge flocks of yellow wagtail covered the uplands while shallow water pools and mudflats were occupied by migratory ducks and waders. We invited Pune's citizens to visit the city's proposed bird sanctuary, we arranged visits of school childrenand even published a brochure describing the birdlife of the area. A day was set to inaugurate our "Sanctuary" and whom could we think of inviting but our beloved Doctorsahib

(that is how I used to address Salim Ali). He came, was greeted by squadron after squadron of flying wagtails who appeared to salute him as he advanced towards the inauguration site. It was a gala event for Pune's citizens who thronged to witness the inauguration of an exceptonal santuary right within an urban area. The media covering the event was quite enthusiastic and the Grand Old Man became a symbol of nature conservation throughout Maharashtra.

The climax of my association with Doctorsahib followed soon when WWF-India sponsored an expedition to Ladakh to find the whereabouts of Blacknecked Crane, an endangered species. I joined the expedition as representative of WWF-I. The one and half month that we spent in the high altitude cold desert of Ladakh resulted in the discovery of the breeding areas of the Blacknecked crane and was punctuated with many a humorous incident when rows of pateints awaited Doctorsahib to administer drugs and medicines! Later I was duly encouraged by Doctorsahib as I took research on Blacknecked crane in Ladakh and its wintering grounds in Bhutan and Arunachal Pradesh. He also liked the idea of organizing an annual meet of birdwatchers of Maharashtra to discuss birdwatching and conservation. He was the chief guest of the meet we organised in Aurangabad.

He became a close friend of our family, visited Pune quite often, relished our homely recipes and especially cakes made by my wife swati. This close association continued till he had to retire to Kihim where he was attended by only servant who was also a cook. We once visited him in Kihim and my wife prepared a special meal for him to his utter surprise and delight. That was our last meal with him.

I later learnt that he was back in Mumbai, had to undergo a surgery and was recovering. I went to see him in Bandra, offered some homegrown flowers and wished him well. He appeared cheerful, thanked me for my gesture and after a brief talk, said he felt like sleeping. I took leave of him and returned to Pune the same evening. Next morning All India Radio spread the grave news, Salim Ali died in sleep during the night. We felt stunned but I consoled myself that I could see him before he left for his heavenly abode.

The same evening I could pay my tribute to the Grand Old Man over All India Radio, Pune.

Prakash Gole

(This article is reprinted here to commemorate the memory of Dr. Salim Ali, India's renowned ornithologist. This is an article from Prakash Gole's archival collection.)

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Foreword

The far reaching and global impact of the COVID-19 pandemic affected many regularly scheduled events and activities across the globe. The Journal of the Ecological Society was not immune to the virus impact and we had to make the difficult decision to delay publication of the 2019 issue. The result is the combining of editions 32nd, 33rd for years 2019 and 2020 into this double issue that we are gratified to publish this year.

Celebrating the 125th birth anniversary of the great ornithologist Dr. Salim Ali, this issue reprints an article by Prakash Gole on Dr. Salim Ali. In addition to research papers and articles this issue also puts a focused spotlight on Rivers.

Since its inception the Journal has published articles explaining and identifying the problems and root causes of what is ailing our environment. Quite often it can be observed that root causes point to unwarranted interventions in natural ecosystems for development. In this edition we have articles exploring alternative, ecology friendly development solutions. In the research article "Wild Edible Plants of Nutritional and Medicinal Significance to the tribes of Palghar, Maharashtra, India" the authors have not only documented species of plants but detailed the preparation processes in their use. How and what part of the plant the tribal folks use, how they collect, and store have all been painstakingly documented for 162 wild plant species. This is crucial work as the traditional use and knowledge of wild edibles is eroding rapidly. Further research is of course needed to establish if surplus production of such wild edibles would be feasible (beyond the needs of the local population) before marketing of the same.

The next research article on the "Presence of Pangolin through Camera Trap Assessment in Ratnagiri District of Northern Western Ghat of Maharashtra, India" contributes invaluable data on the enigmatic Pangolin, an endangered relic of the dinosaur age having survived 80 million years. Unfortunately, Pangolins are being poached and slaughtered for commercial gain and may very well be on the brink of extinction. Therefore, it is vitally important to assess the population before it is too late. The authors have ingeniously worked with the indigenous community to track the burrows and setup Camera traps. Their efforts have been rewarded with 7 out of 12 burrow traps indicating presence of Pangolins. Author's analysis shows that the Pangolin have a particular preference for burrows in rocky scrubland.

Also making invaluable contributions to the data on species and their habitat choices are two articles, one on the flora along the riparian zone of the Mutha river in Pune, "Documentation of Riparian Biodiversity of an Urban River stretch – A citizen's Initiative." and the other on the butterflies, "Butterfly Diversity of the ARAI hills." The documentation of biodiversity along the urban stretch of river Mutha creates data for a particular time and space. It will be of use to compare changes that might take place in future. The latter is a great illustration of the biodiversity that can survive even within a densely populated city if given the chance. The authors observe a total of 87 species and have also identified larval host plants that support this high diversity, this information is valuable for the implementation of such corridors for biodiversity.

The special section of this journal on rivers includes three articles related to diverse aspects of rivers. All three make the case for the revival of Pune's Mula-Mutha river system. They describe the repercussions of human interventions and disturbances on the natural drainage system. "The story of Jeevitnadi" describes the author's efforts in raising the public awareness about the river's polluted condition and of the opportunity to create a healthful public space along the river. The authors have worked with great dedication on raising public awareness of the dire state of Pune rivers. Their perseverance extended further into engaging the public on several hands on restoration experiments. A really remarkable and commendable endeavor. The story of their efforts including various experiments and their experiences in tackling this difficult task are very well documented in this article. The story of urban rivers does not end with citizen awareness of the condition of the river, it also needs awareness about the efforts of civil authorities to execute river development projects. Such development plans are often completely ecologically unaware. The Pune Municipal Corporation's "riverfront development project" is no exception. Its design reveals major interventions in the natural system, proposing building of concrete

banks. The article, "Ecological guidelines and recommendations for Mula-Mutha Riverfront Development" focused on the assessment of the environmental impact of the riverfront development project and suggests much better eco-friendly alternative designs. The guidelines proposed by the study could very well apply to any urban river stretch. The third article on rivers "Flood Fury of Pune : Understanding the Tributaries" is about analyzing the causes of the recent unusual flood events that badly affected Pune city. The 2020 flood of the Ambil Odha, a prominent tributary of the Mutha river, affected many citizens in an area far away from the main Mutha river. Such floods are unusual occurrences, the watershed of this tributary has been completely modified and these changes such as high proportion of hard scape in the watershed can exacerbate such events. The article sheds light on such root causes, the role of geology and the impact of development on the watershed. The photographic documentation of the repercussions is particularly illustrative.

We felt it was appropriate to reprint a couple of archival articles related to rivers to round out the special section on rivers. The article "Birds of a Polluted River" by late Dr Prakash Gole, documents the state of bird diversity, observations linking various aspects of the river ecosystem, long term observations to understand population dynamics and how external factors control the river ecosystem are the highlights of this article. A useful reference for comparing the present-day bird fauna with the historical data. The second archival article on "Flood Pulsing in Restoration : A Feasible Alternative for India" explains the natural flood pulsing behavior of rivers and how the river ecosystem extends laterally beyond the channel and banks into the flood plain. Flood plains are a critical feature responsible for creating high biological productivity in the river ecosystem. Lateral exchange of water, nutrients and organisms is a dynamic interaction supporting aquatic, terrestrial transition zone (ATTZ) and how it is impacted by building of dams, levees, bunds etc. The loss of such wide water systems is explained in the article by giving examples from all over the world. Examples of restoration of this lateral system are also given in this article. The famous example of simulation of flood pulsing by controlled release of water from dam has been tried with some success in the Grand Canyon of U.S. since 1996 is cited here. Reading the original article will enhance the understanding of river ecosystems and the importance of flood pulsing.

The article "Deploying Modern ICT tools to Develop Gramsabha Level Plans for Conserving and Managing Community Forest Resources" is about creating a model to sustainably harvest forest produce in the areas of community forest where rights to collect non timber produce is given by 'Forest Rights Act 2006'. It is a different model than that of a Forest Department, as Gramsabha plan emphasizes sustainable collection, conservation of biodiversity, with a modern landscape perspective. It is a welcoming gesture, as more than 6000 gramsabhas have been granted community rights. It will be followed widely as modern gadgets like mobile phones have created user friendly facilities, and tribal youth have enough basic education to handle these gadgets.

Finally, this issue re-publishes "Animal Agriculture Is the Leading Cause of Climate Change – A White Paper". This important paper shows the contradictions in the calculation of CO2 emissions by the IPCC and postulates how animal agriculture is the leading cause of climate change based on a 'Global Sensitivity Analysis'. The paper also advocates transitioning to a global plant-based economy to solve the climate challenge.

This journal has always put a focus on root cause analysis of environmental problems and on restoration of natural systems. The selection of research papers and articles in this issue is in keeping with this tradition and the editors hope the readers find the selection as enlightening and enjoyable as past issues.

Swati Gole

Wild Edible Plants of Nutritional and Medicinal Significance to The Tribes of Palghar, Maharashtra, India

Yatish Lele, Bhargavi Thorve, Swati Tomar, Anjali Parasnis

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Abstract

Wild edible plants (WEP) are an important component from the perspective of tribal diet. There are various traditional practices and beliefs in relation to the use of wild edibles among various tribal communities in Maharashtra. In this study, the WEP found in Jawhar block of Palghar district and detailed information on the local usage for medicine or food purpose has been documented. With this, the traditional methods of preparation, collection and storage of these edible wild plants has also been documented. The present paper presents a total of 162 species of WEP, out of which almost 74% are consumed as food, 14% possess medicinal significance while 12% of the species exhibit both dietary and medicinal significance. This type of study could contribute in recording the traditional heritage of food culture and generate awareness about the importance of wild edible species. Documentation of these wild plant species can help in commercialization and domestication of the wild varieties and their entry into urban marketplaces to generate higher revenue for the farmers. Wild edibles could prove to be a remedy to food scarcity, a source of nutritional security and improve the economy in tribal areas.

Keywords : *Tribal communities, Wild edible plants, Traditional knowledge, Jawhar, Western Ghats*

Introduction

Over the millennia, forests have played a key role as a source of food, fodder, fuel and medicine in the lives and livelihood of the forest dwelling communities. Although the societies primarily depend on agriculture for food, millions of people like the forest dwelling communities and rural population, have traditionally depended on the wild plant resources (Panda, 2014). Wild edible plants (WEP) are widely used for various purposes mostly as a source of food and medicine by the tribal communities all across the world. These tribal communities have acquired immense knowledge about the use of wild plant species based on the local needs, preferences, customs, and habit (Jain and Tiwari, 2012). Even today, indigenous people continue to follow many traditions and have long experience and close association with the nature. For example, Vietnamese commonly use Chinese herbal medicine and a set of indigenous folk practices referred to as "Southern medicine" in an effort to cure any disease (Jenkins, 1996) whereas, 'Ayurveda' in Indian Folk-medicine is still an important method of treatment using the plant resources (Deshmukh and Waghmode, 2011).

A number of wild plants significantly contribute to the human diet and food security across the world. In central Italy, 126 wild plants from 39 families are consumed (JmanRedzic, 2006) and wild greens are eaten raw in salads, or in boiled mixtures, as 'blood

cleansing' and 'intestine cleansing' agents (Pieroni, 2000). In Vietnam, over 90 species of WEP have been documented (Ogle et.al, 2003). Several studies on dietary uses of edible wild plants are forthcoming to tackle malnutrition and famine conditions faced by the tribal population of Nigeria which is prone to droughts and crop failure (Lockett et al, 2000). Hence the WEP are also significant and usually considered as an Emergency food during the adverse conditions such as floods, droughts and famine.

Similarly, it has also been estimated that there are around 800 varieties of wild species being consumed in India (Nivedita, 2017). The Indian Himalaya reveals the richest biodiversity of WEP with over 675 wild plant species used as food and their various parts are either consumed raw, roasted, boiled, fried, cooked or in the form of oil, spice, seasoning material, jams, and pickles by the native communities (Samant, 1997). The Garo tribe in Meghalaya uses around 38 species of wild plants as vegetables and 33 species are consumed raw or cooked (Singh et al, 2012); 28 species of wild plants are consumed as vegetables by aboriginal of Vindhyan plateau in Central India and over 45 plant species are consumed as emergency food by the tribes inhibiting Pachmarhi biosphere reserve in Madhya Pradesh (Jain and Tiwari, 2012). On the other hand, an ethnobotanical study on edible wild plants in a few chosen districts of Maharashtra reports 29 wild edible fruit plants consumed by tribal communities from Kalsubai- Harishchandragad wildlife sanctuary (Deshmukh and Vidya, 2010); 101 species were recorded used by tribes residing in Toranmal plateau of Maharashtra (Sharma and Mujumdar 2003) and 30 plant species, used by the tribal and non-tribal of Nasik district for ethnomedicinal purposes was recorded by Patil and Patil (2005).

This clearly indicates that the wild edibles form a major and prominent source of food and medicine in the daily routine of the tribal and non-tribal. Wild edibles such as tubers and corms are also frequently consumed to fulfil the critical gaps created by the agricultural shortfall, natural disasters, disease epidemics and famine and thus act a response to emergency (Belcher, 2005). However owing to the land use changes and yearlong availability of fruits and vegetables in the local markets, the use of wild edibles has been restricted which shall in turn threaten the traditional knowledge of the use of these wild plants. As a result, the ethnobotanical studies need to be carried out to document the important sources of nutrition which played an important role in their diet and medicine.

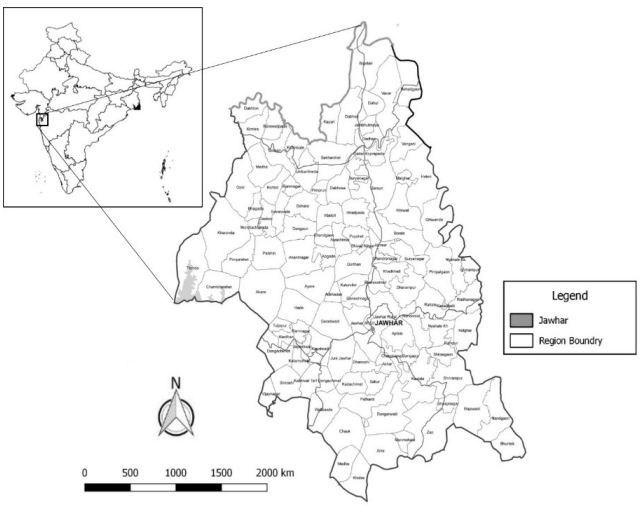
This study documents the traditional knowledge of wild edibles in the Jawhar region of Maharashtra, India and provides an inventory of wild plants consumed by the tribal communities of Jawhar block of Palghar district in Maharashtra. The plants have been recorded along with their availability, seasonality, uses and traditional recipes.

Methodology

Study Area

Jawhar block from Palghar district, Maharashtra state, India was identified as the site for conducting the study. Known as "Mahabaleshwar (A famous hill station in India) of Palghar district", Jawhar taluka is located at 19.92°N 73.23°E at the height of approx. 473 meters above sea level (Fig. 1). The area receives an average rainfall of around 3000 mm (Chotte et al, 2014). Being part of the Northern Western Ghats, the area is rich in biodiversity with a moist deciduous type of forest ecosystem (Champion and Seth, 1968). The region is inhabited by different tribes like Thakur, Mahadev Koli, Warli, Katkaris and Kokana who are partly dependent on different plants species for food and medicinal purposes.

Palghar district is well known for the WEP consumed by the tribal population (Sonawane et al., 2012; Chotte et al, 2014; Oak et al 2015; Shivprasad et al2016). But there is no proper documentation and validation of the WEP of Jawhar region. The tribal communities in Jawhar also depend on the WEP for their dietary and medicinal purposes apart from the agricultural produce. These WEP are largely harvested



Map 1: Location of the study site

from the local forest areas present around villages. Today, expansion of agricultural area and over-exploitation of the Non Timber Forest Produce (NTFP) have resulted in the degradation and deforestation which may threaten the ecological and biological value of the remaining tracks of forests in future (Belcher, 2005).

One of the major issues faced by the tribal population in this region is malnutrition. Malnourishment remains a major problem in the region mostly in the women and children below age group of 6 years. Studies have reported the issue of malnourishment to be severe in case of infants and children (Hatekar and Rode., 2003; Dimri et.al, 2012). One of the possible reasons for this severity could be lack of knowledge about healthy diet, ignorance towards wellbeing and proper sanitation or lack of food variety and absence of purchase power to procure nutritious food. Today, local livelihoods are mainly based on the small scale farming with cultivating sustenance crops such as rice, nachni etc; fruit crops such as banana and chickoo. The other sources of income mostly include labour wages in the nearby cities such as Thane and Mumbai.

Methodology

The study was conducted from December 2014 to March 2016. Extensive review of literature was undertaken in order to collate information about the wild edible species from Jawhar block. Focus Group Discussions (FGD) were conducted in 25 tribal villages namely Tasupada, Madvihira, Kahandolpada, Umbrachapada, Bhagada, Savarpada, Malghar, Khuripada, Chibhadepada, Kogade, Jamsar, Sarsun, Umbervihir, Khambala, Behedpada, Dhodipada, Barwadpada, Pachgud, Kalamvihira and Kasatwadi which were selected by stratified random sampling. The local names of the plant species and their significance to the community was documented using a questionnaire. The discussions consisted of men, women, youth, elderly people, local medicine men (locally known as Vaidu) as well as plant experts (botanists) to understand the varied significance of wild edibles to each group (in this case total, N= 323).

Participatory transect surveys were undertaken in the forest areas with the help of the local tribes to identify and validate the plant species. Flora of Maharashtra aided in the identification of plants on field (Almeida, 1996, 1998, 2001a,b; 2003a, b; 2009 a, b). The surveys were undertaken seasonally as the floral pattern is subjected to change as per the season. The points to be surveyed in the forest were marked using Google Earth software. On field, these points were identified, tracked and marked using a Global Positioning System (GPS). The relevant plants observed at random were also recorded to collate and update the checklist. This approach helped document all the wild edibles present in the area irrespective of their significance to the tribal communities in the vicinity.

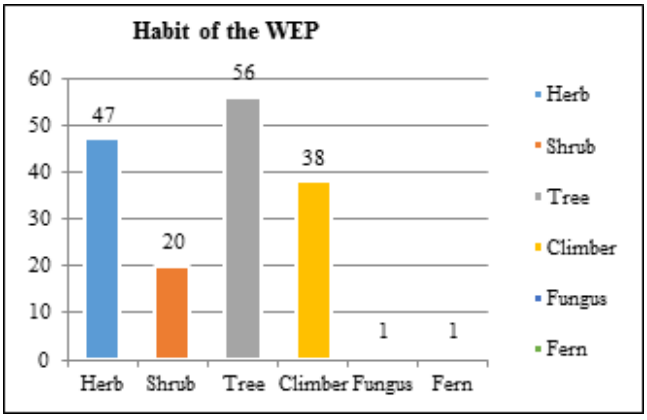
Results and Discussion

WEP and Perceptions

WEP are being consumed by all the strata of the tribal community throughout the year. A total of 162 species of WEP were reported from the survey. The details of the reported plant species such as the local names of the plant, season of availability and significance of the wild edible plant and the method of consumption is provided below in Table 1.

The study indicated plants belonging to 65 families out of which maximum plants consumed were from Leguminosae family (19 species). The top ten families following Leguminosae were Cucurbitaceae (12 species), Malvaceae (10 species), Dioscoreaceae (7 species), Amaranthaceae (6 species), Araceae (6 species), Lamiaceae (6 species), Poaceae (5 species), Rubiaceae (5 species) and Apocynaceae (4 species). As it could be observed from Fig. 2, trees have constituted 34% of the WEP species followed by herbs (29%), climbers (23%), shrubs (12%), Fungus(mushrooms) (1%) and fern species (1%).

Although the WEP form a crucial part of the diet of the tribal communities, very few of them were aware about of the nutritional aspect of the wild edibles. The knowledge of medicinal uses of plants species was restricted to the older generation or the Vaidu'. It was found that out of the 162 species of wild edibles, almost 74% of the wild edibles were consumed as food and 14% of the species possess medicinal significance



Graph 1 : Life forms of the WEP recorded in Jawhar

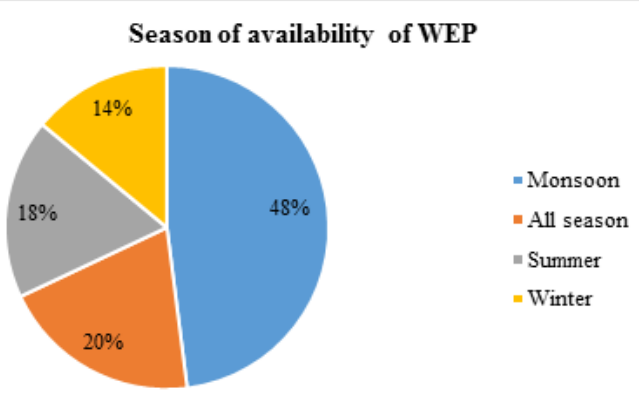
while 12% of the species are characterised for both dietary and medicinal significance.

Seasonal availability of wild food resources

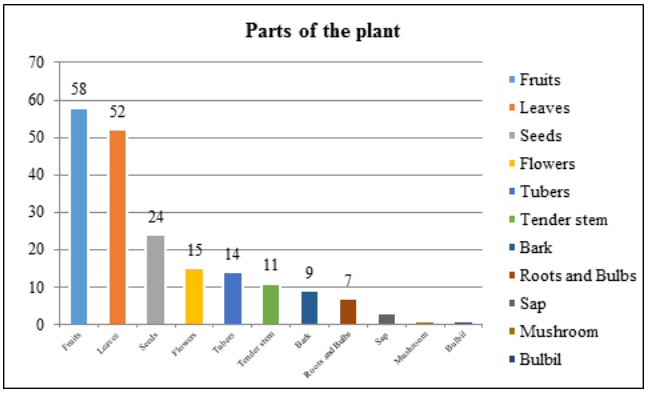
Seasons play an important role in the pattern of consumption of wild edibles by the tribal communities. A total of 48 % species are seen in monsoon (June-September) while 20% plants are found throughout the year, 18% in summers (February- May) and 14 % in winters (October- January) (Fig. 3).

Different processes of the plant such as flowering, fruiting, and leafing seasonal and hence different plant parts are consumed in different seasons. Of these30% consumption was of fruits, followed by leaves (27%), seeds (12%), flowers (8%), tubers (7%) and followed by others (Fig.4).

The analysis shows that most of the wild edibles are consumed during the monsoon. Most of the fruits, flowers and leaves of different plant species are harvested for consumption during monsoons. The food items being highly perishable are mostly consumed immediately after harvesting while some species are stored in the form of pickles or dried forms (Chotte A, 2014). Tree species such as Pterocarpus marsupium, Anogeissus latifolia are perennial thus the leaves, bark and sap of these plants are utilized on a regular basis. The months of winter and summer are most vulnerable to food shortages due to water scarcity and less availability of edible plant species in the wild. In such situations, tubers are the preferred due to their availability in the dry season. The tribal communities depend on the agricultural produce during this time of the year.



Graph 2 : Season of availability of the WEP for consumption



Graph 3 : Parts of the plant consumed by the tribal communities of Jawhar

Consumption of Significant Species

The tribes in Kasatwadi village consume a fern species, Athyrium hohenackerianum, (Akri) which is a unique observation from the study area. The studies reporting the consumption of WEP from Maharashtra have not yet reported such observation from different parts of the state. Thus this is the first of its kind recorded observation of consumption of fern as food. But this observation was recorded only from one village, Kasatwadi, while communities from other villages are unaware about the significance of the fern. Another species, Justicia procumbens (Sharambal) was also found to be consumed only in the Kasatwadi village. The reason for the same was unknown. Species consumed by different villages also varied. Villages situated near river were found to consume aquatic plant species such as Cryptocoryne spiralis (Sol) and Marsilea quadrifolia (Girjala) whereas villages situated up-hill did not have access to these and thus were ignorant about its availability.

Some of the plant species have also been domesticated such as Momordica dioica (Karli/Karele), Dioscorea bulbifera (Kadukand), Amorphophallus paeoniifolius (Suran), Curcuma longa (Halad/Haldi) and Basella alba (Mayalu/ Indian Spinach) which are cultivated in the backyard /kitchen gardens. Germplasm of these plants are stored until the next season of plantation. Few wild edibles are found to be consumed only in few villages due to the geographical differences, lack of availability and accessibility and lack of knowledge about the plant species. It was also found that few wild edibles such as tubers, bamboo, leafy vegetable, fruits and flowers also contribute to the economics of the tribal communities. The tribes sell the WEP in the local market at Jawhar or sell it directly by

setting up small stalls at the road sides or highways.

Conclusion

The regular diet of the tribal people of Jawhar consist of rice, finger millet (nachni/raagi), urad and few locally available vegetables. They mostly depend on rain-fed agriculture for food and sell the surplus. Forest land is gradually getting converted into agriculture land, with the growing demand for food due to increasing population, but climatic variations are negatively impacting the agricultural produce. Shifting cultivation is the common practice and increasing deforestation and mono-culture are changing the landscape which is a threat to the availability and abundance of wild edibles. This could also be one of the reasons why the tribal communities are increasingly dependent for food on agricultural produce available in the market. Moreover, lack of knowledge about WEP in the younger generation and the lack of livelihood opportunities leads to migration which again results in to lesser consumption of wild edibles.

Traditionally used wild edibles have enormous medicinal potential and could be an excellent source of nutrition and vitamins as a supplementary food. This immense knowledge gained through trial and error practices over several decades needs to be documented as they are an integral part of the Indian culture. It has been reported that out of an estimated portfolio of 30,000 edible plant species recorded worldwide, man depends only on 12 crops for the bulk of its nutritional requirements (Padulosi et al, 2011). This implies the great potential of wild edibles in the context of food security. The decreased use of wild edibles due to modernization and lack of knowledge among the younger generation are the major challenges. Thus it is important to conduct various studies on the commercial potential for ensuring the conservation and sustainable utilization of these species to hold a food-secure future.

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Table 1: List of WEP consumed by the tribal communities along with their significance and method of consumption

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
1.	Aagheda/ Achira	*Achyranthes-aspera* L.	Amaranthaceae	Herb	Monsoon	Tender leaves	Food and Medicinal	Tender leaves are soaked in water and cooked with onion and local masalas as a vegetable.	Root powder extract is consumed during tooth ache.
2.	Aalambi/ Alimbi	*Pleurotus sps*	Agaricaceae	Fungus	Monsoon	Whole mushroom	Food	Mushrooms are boiled and cooked with local spices.	-
3.	Abay/ Abai/ Chopdi	*Canavalia gladiata* (Jacq.) DC.	Leguminosae	Climber	Monsoon	Pods	Food	The young pods are boiled and are cooked with onion and chilly. The excess boiled water is drained.	-
4.	Adulsa	*Justicia adhatoda* L.	Acanthaceae	Shrub	All season	Leaves	Medicinal	-	Decoction of leaves is consumed during cough.
5.	Akri/ Akkadghad	*Athyrium hohenackerianum* T. Moore	Athyriaceae	Fern	Monsoon	Tender shoots	Food	Young shoots are boiled and cooked as vegetable in local spices.	-
6.	Aliv/Alav	*Meyna laxiflora* Robyns	Rubiaceae	Tree	Monsoon	Fruits	Food (Sold in the market during season)	Directly consumption of fruits.	-
7.	Alu/ Arabi/ Tera/Teri	*Colocasia esculenta*(L.) Schott	Araceae	Herb	Monsoon	Leaves and Tuber	Food	1. Leaves are steamed and layered with gram flour to make local dish called 'Wadi'.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
								2. Green curry or 'Saag' is also prepared by using the leaves. 3. Tubers are boiled and cooked as vegetable.	
8.	Amba	*Mangifera indica*L.	Anacardiaceae	Tree	Summer	Bark and Fruits	Food and Medicinal	Directly consumption of fruits	Bark decoction is consumed during stomach ache
9.	Ambadi	*Hibiscus sabdariffa*.L.	Malvaceae	Herb	Monsoon	Leaves and Fruits	Food and Medicinal	1. Initially leaves are dried and cooked as vegetable using local masalas. 2. As it is sour to taste only small portion is added just to add taste while cooking curry or fish.	A small portion of the dried fruit is boiled and the water is consumed to cure cough or stomach infection.
10.	Ambuti	*Begonia crenata* Dryand	Begoniaceae	Herb	Monsoon	Leaves	Food	Leaves are consumed directly or added in vegetable for its sour taste.	-
11.	Asand	*Bridelia retusa* (L.) A.Juss.	Phyllanthaceae	Tree	Monsoon	Fruits and Bark	Food and Medicinal	Directly consumption of ripe fruits	Bark extract is consumed during ear ache. Also effective on stomach ache.
12.	Avala	*Phyllanthus emblica*L	Phyllanthaceae	Tree	Winter	Fruits and Stem	Food and Medicinal	Ripe fruits are consumed raw or pickeled through sun drying.	Stem extract is consumed during dental pain.
13.	Badade	*Arisaema murrayi* (J. Graham) Hook.	Araceae	Herb	Monsoon	Tuber	Food	Tubers are soon boiled and cooked and consumed directly or as vegetable.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
14.	Bafali/ Baphali	*Heracleum grande* (Dalzell & A. Gibson) Mukhop.	Apiaceae	Herb	Monsoon	Leaves, roots and seeds	Food and Medicinal (Sold in the market during season)	1. Steamed leaves are saute on oil to make vegetable. 2. Seeds are used in preparation of sauce 'chatni'.	Seed powder and root decoction is used to cure stomach pain.
15.	Bahava	*Cassia fistula* L.	Legu-minosae	Tree	Summer	Flowers	Food	Flowers are boiled and cooked with onion and chilies. The water is drained after thoroughly after cooking.	-
16.	Bamboo/ Vasate	*Bambusa bambos*(L.) Voss	Poaceae	Herb	Mon-soon	Shoots	Food (Sold in the market during season)	Young shoots used to prepare vegetable as well as preserved in the form of a pickle.	-
17.	Bandgul	*Dendro-phthoe falcata*(L.f.) Ettingsh.	Loranth-aceae	Shrub	Winter	Fruits	Food	Fruits are consumed directly.	-
18.	Beheda	*Terminalia bellirica* (Gaertn.) Roxb.	Combreta-ceae	Tree	Monsoon	Fruits and Seeds	Food and Medicinal	Seeds consumed raw by children only after the fruit dries and breaks. Too much consumption of seeds may cause giddiness in children.	Powder of fruits is consumed during cough.
19.	Bel	*Aegle marmelos* (L.) Corrêa	Rutaceae	Tree	Summer	Fruits and Bark	Food and Medicinal	Ripe fruits are directly consumed or added in juice 'Sharbat'	Bark decoction consumed during dental pain.

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
20.	Bhagar/ Varai	*Panicum miliaceum* L.	Poaceae	Herb	Winter	Seeds	Food	1. Mostly consumed by preparing Soup 2. Grains are boiled to prepare 'Khichadi' (Type of rice item) by adding local ingredients.	-
21.	Bharangi	*Rotheca serrata* (L.) Steane & Mabb.	Lamiaceae	Shrub	Monsoon	Leaves	Food	Young leaves are used to make vegetable.	-
22.	Bhokar	*Cordia dichotoma* G.Forst.	Boraginaceae	Tree	Summer	Fruits	Food	Raw fruits are pickled while ripe fruits are directly consumed	-
23.	Bhopla/ Bhopala/ Dangar/ Dongar-bhaji	*Cucurbita maxima* Duchesne	Cucurbita-ceae	Climber	Monsoon	Fruits	Food	Fruits are boiled and cookec as a vegetable.	-
24.	Bibba	*Semecarpus anacardium*L.	Anacardia-ceae	Tree	Summer	Fruits and Seeds	Food	1. Fleshy part of fruit is consumed directly. 2. Seeds known as Godambi are consumed raw.	-
25.	Bivala/ Beeja	*Pterocarpus-marsupium* Roxb	Legumino-sae	Tree	All season	Leaves and Bark	Food and Medicinal	Young leaves boiled and cooked used as vegetable	Bark powder used to cure dental problem
26.	Bondara	*Lagerstrom-ea parviflora* Roxb.	Lythara-ceae	Tree	All season	Leaves	Food	Tender leaves are mixed with other wild vegetable and cooked to remove itchiness occurring in throat.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
27.	Bor	*Ziziphus jujube* Mill.	Rhamnaceae	Tree	Winter	Fruits	Food	Direct consumption of fruits.	-
28.	Borod	*Echinochloa colona* (L.) Link	Poaceae	Herb	Monsoon	Seeds	Food	Seeds are used in the preparation of sweets.	-
29.	Chaivel/ Chaikand/ Chayavel	*Dioscorea alata*L.	Dioscoreaceae	Climber	Monsoon	Tubers	Food	Tubers are boiled, cooked and consumed as vegetable.	-
30.	Chavali	*Vigna unguiculata* (L.) walp.	Leguminosae	Climber	Monsoon	Seeds	Food	Seeds are boiled and cooked as vegetable.	-
31.	Chibud/ Muskmelon	*Cucumis melo* L.	Cucurbitaceae	Climber	Summer	Fruit	Food	Fruits are consumed directly on ripening.	-
32.	Chinch	*Tamarindus indica* L.	Leguminosae	Tree	Summer	Ripe fruits	Food	1. Ripe fruit are added in vegetables to add the sour flavor. 2. Riped fruits are also consumed directly.	-
33.	Chirambot	*Physalis minima* L.	Solanaceae	Herb	Monsoon	Fruits	Food	Ripe fruits are consumed directly.	-
34.	Chirati	*Mukia maderaspatana*(L.) M.Roem.	Cucurbitaceae	Climber	Monsoon	Fruits	Food	Ripe fruits are consumed directly.	-
35.	Chunch/ Chuch/ Chinchnuk	*Corchorus olitorius.* L	Malvaceae	Herb	Monsoon	Leaves	Food	Young leaves are boiled and cooked as vegetable.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
36.	Dauda	*Sterculia gutata* Roxb. ex G.Don	Malvaceae	Tree	Winter	Seeds	Food	Roasted seeds are consumed directly.	-
37.	Dehagadi/ Dighavadi/ Konchi	*Dioscorea wallichii* Hook.f.	Dioscoreaceae	Climber	Monsoon	Tender leaves and shoots	Food	Tender leaves and shoots are boiled and cooked with local masalas to be consumed as vegetable.	-
38.	Dhavda/ Dhamoda	Anogeissus latifolia (Roxb. ex DC.) Wall. ex Guillem. & Perr.	Combretaceae	Tree	All season	Gum	Food	Gum is edible and added in various curries and vegetables.	-
39.	Dhayati	*Woodfordia fruticosa*(L.) Kurz	Lytharaceae	Shrub	Winter	Flowers	Food	Flowers are not only used to extract nectar but they are also cooked and consumed.	-
40.	Dudhi	*Lagenaria siceraria* (Molina) Standl.	Cucurbitaceae	Climber	Monsoon	Fruits	Food	Fruits are boiled and cooked as a vegetable.	-
41.	Erand	*Ricinus communis* L.	Euphorbiaceae	Shrub	All season	Seeds	Medicinal	-	Oil is extracted from the seeds of Erand which are used as laxative during stomach problems.
42.	Fanas	*Artocarpus heterophyllus* Lam.	Moraceae	Tree	Summer	Fruits	Food	Direct consumption of fruits.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
43.	Fatangadi/ Phangota/ Phatangdi/ Ambattingra	*Embelia tsjerium-cottam* (Roem. & Schult.) A.DC.	Primulaceae	Shrub	All season	Leaves and Seeds	Food and Medicinal	Leaves are boiled and cooked as vegetable using local masalas.	Seeds are consumed during stomach pain.
44.	Gagola	Ipomoea muricata (L.) Jacq.	Convolvulaceae	Climber	Monsoon	Fruits	Food	Fruits are consumed only after removal of the seed and stir fried with onion and local masalas to make vegetable.	
45.	Gala/ Gela Ghela/ Gal	*Catunaregam spinosa* (Thunb.) Tirveng.	Rubiaceae	Tree	Monsoon	Tender fruits	Food	Tender fruits are boiled and cooked in niger seeds and local masala to be consumed as vegetable.	
46.	Garbhanda	*Leea asiatica*(L.) Ridsdale	Vitaceae	Shrub	Monsoon	Leaves	Food	This wild edible was recorded in Jawhar but the tribes do not consume the same. In other parts of Maharashtra, the leaves are cooked and consumed.	
47.	Garbhend	*Thespesia lampas* (Cav.) Dalzell	Malvaceae	Shrub	Monsoon	Roots	Medicinal	-	The roots decoction is consumed during yellow urination.
48.	Gavar	*Cyamopsis tetragonoloba*(L.) Taub.	Leguminosae	Shrub	Winter	Fruits	Food	Fruits are boiled and cooked as vegetable.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
49.	Gavathi-udid	*Vigna mungo*(L.) Hepper	Leguminosae	Herb	Monsoon	Seeds	Food	Seeds are cooked in the form of curry or vegetable.	-
50.	Gholu	*Portulaca oleracea* L	Portulacaceae	Herb	Monsoon	Leaves	Food	Leaves are boiled and cooked as vegetable.	-
51.	Ghugur-val	*Flacaurtia indica* (Burm.f.) Merr.	Salicaceae	Tree	Monsoon	Fruits	Food	Direct consumption of fruits.	-
52.	Girjala	*Marsilea quadrifolia*L.	Marsileaceae	Herb	Winter	Leaves	Food	Leaves are boiled and cooked as vegetable.	-
53.	God Kanda/ Karanda	*Dioscorea esculenta* (Lour.) Burkill	Dioscoreaceae	Climber	Monsoon	Bulbil and Tuber	Food (Sold in the market during season)	Bulbils and tubers are boiled and cooked as vegetable.	-
54.	Gometi	*Solena amplexicaulis*(Lam.) Gandhi	Cucurbitaceae	Climber	Monsoon	Tuber	Medicinal	-	Tuber powder is consumed to increase the appetite in children.
55.	Gulvel	*Tinospora sinensis* (Lour.) Merr.	Menispermaceae	Climber	Monsoon	Stem	Medicinal	-	Stem decoction is consumed during acidity and heat problem.
56.	Gunj	*Abrus precatorius* L.	Leguminosae	Climber	Monsoon	Leaves	Food and Medicinal	Leaves are directly consumed after meal or add in 'Pan'	Leaves are used as medicine on cough and it also helps in digestion

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
57.	Halad	*Curcuma longa* L.	Zingiberaceae	Herb	All season	Rhizome	Food	Rhizome powder is used in daily cooking.	-
58.	Halinda	*Vigna vexillata*(L.) A.Rich.	Leguminosae	Climber	All season	Tuber	Food	Tuber is consumed raw or is boiled and cooked as vegetable.	-
59.	Hirda	*Terminalia chebula* Retz.	Combretaceae	Tree	Monsoon	Fruits	Medicinal	-	Fruit powder is consumed against cough.
60.	Humb	*Miliusa tomentosa* (Roxb.) J.Sinclair	Annonaceae	Tree	Summer	Fruits	Food	Ripe fruits are consumed directly.	-
61.	Jambhul	*Syzygium cumini*(L.) Skeels	Myrtaceae	Tree	Summer	Fruits	Food	Ripe fruits are consumed directly.	-
62.	Jangali Kanda	*Drimia indica* (Roxb.) Jessop	Asparagaceae	Herb	All season	Bulb	Medicinal	-	Juice of the bulb is consumed during piles.
63.	Jungli-Suran/ Loth/ Shevala	*Amorphophallus commutatus* (Schott) Engl.	Araceae	Herb	Monsoon	Tuber, Tender leaves and Stem	Food (Sold in the market during season)	1. Tubers are boiled and cooked as vegetable. 2. Tender leaves (Loth) are steamed and cooked with onion and garlic. Leaves of 'Bondar' are added while cooking to remove the itchiness. 3. The leaves are also dried and stored for off season consumption. 4. Tender stem (Shevala) is cooked as vegetable.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
64.	Jwari	*Sorghum bicolor* (L.) Moench	Poaceae	Herb	Winter	Seeds	Food	Powdered seeds are mixed with water to make bread.	-
65.	Kadunimb	*Azadirachta indica* A. Juss.	Meliaceae	Tree	All season	Leaves	Medicinal	-	Leaves decoction is used for dental care.
66.	Kadu-kand/ Dukkar-kand	*Dioscorea bulbifera* L.	Dioscorea-ceae	Climber	Monsoon	Tuber	Food	Tuber is kept overnight in the river so as to dissolve the bitter taste. It is then boiled and consumed.	-
67.	Kahandal	*Firmiana simplex* (L.) W.Wight	Malvaceae	Tree	Winter	Seeds and Gum	Food	1. Roasted seeds are consumed. 2. The gum of the plant is also consumed by adding it in various food items.	-
68.	Kaharul	*Bauhinia purpurea* L.	Legumino-sae	Tree	Winter	Young leaves and Buds	Food	Young leaves and buds are consumed as vegetable.	-
69.	Kakad/ Kakhodshi	*Garuga pinnata* Roxb.	Burseraceae	Tree	Summer	Fruits	Food	Fruits are consumed directly and also prepared as pickle.	-
70.	Kakdi	*Cucumis sativus* L.	Cucurbita-ceae	Climber	Summer	Fruits	Food	Direct consumption of fruits	-
71.	Kala kuda	*Wrightia tinctoria* R.Br.	Apocyna-ceae	Tree	Summer	Flowers	Food	Flowers are boiled and cooked in local masalas as vegetable.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
72.	Kali dhaman	*Grewia tillifolia* Vahl.	Malvaceae	Tree	Summer	Fruits, Bark and Roots	Food and Medicinal	Direct consumption of fruits.	1. Root extract is consumed during stomach ache. 2. Bark decoction is consumed during piles and bones joints.
73.	Kali musali	*Curculigo orchiodes* Gaertn.	Hypoxidacea	Herb	Monsoon	Roots	Medicinal	-	Root decoction is useful in treatment of piles and joint pain.
74.	Kamal kakadi	*Nelumbo nucifera* Gaertn.	Nelumbonaceae	Herb	All season	Seeds	Food	Roasted seeds are consumed.	-
75.	Kardai	*Argemone mexicana* L.	Asteraceae	Herb	Summer	Seeds	Food	Seeds are crushed to extract edible oil which is used in cooking purposes.	-
76.	Karli/ Karle/ Karavli	*Momordica charantia* L.	Cucurbitaceae	Climber	Monsoon	Fruits	Food	Fruits are boiled & cooked as vegetable.	-
77.	Kartoli	*Momordica dioica* Roxb. exWilld.	Cucurbitaceae	Climber	Monsoon	Fruits	Food (Sold in the market during season)	Fruits are boiled & cooked in oil as vegetable.	-
78.	Karval/ Karmal	*Dillenia pentagyna* Roxb.	Dilleniaceae	Tree	Summer	Flowers	Food	Flowers are used in preparation of vegetable.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
79.	Karvand/ Karvanda	*Carissa carandas* L.	Apocynaceae	Shrub	Summer	Fruits	Food	1. Fruits are consumed directly on ripening. 2. Raw fruits are also used in pickles.	-
80.	Kate Math	*Amaranthus spinosus* L.	Amaranthaceae	Herb	Monsoon	Leaves	Food (Sold in the market during season)	Leaves are fried and cooked in oil and masalas as vegetable.	-
81.	Katesawar	*Bombax ceiba* L.	Malvaceae	Tree	Summer	Flowers	Food	Flowers are boiled and cooked as vegetable.	-
82.	Kavadar	*Ensete superbum* (Roxb.) Cheesman	Musaeae	Herb	Monsoon	Flowers and stem	Food	Stem and flower are boiled and consumed as a vegetable.	-
83.	Kavalamba	*Trichosanthes tricuspidata* Lour.	Cucurbitaceae	Climber	Monsoon	Roots	Medicinal	-	Roots decoction consumed during urinary infection.
84.	Kavisha/ Kavisa	*Firmiana colorata* (Roxb.) R.Br.	Malvaceae	Tree	All season	Bark	Medicinal	-	Bark decoction is consumed during urine infection and stomach pain.
85.	Kawla	*Smithia conferta* Sm.	Leguminosae	Herb	Monsoon	Leaves	Food	Young leaves cooked with spices as vegetable.	-
86.	Keni	*Commelina benghalensis* L.	Commelinaceae	Herb	Monsoon	Leaves	Food	Young leaves are boiled and cooked in oil as vegetable.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
87.	Khadaktera/ Teralu	*Ariopsis peltata* Nimmo	Araceae	Herb	Monsoon	Leaves	Food	1. Leaves are cooked as vegetable with oil and onion. 2. Leaves are also rolled to make spirals along with chana paste which is consumed after shallow frying. 3. Leaves are directly added to curry as garnish.	-
88.	Khajur/ Shindi	*Phoenix sylvestrus* (L.) Roxb.	Arecaceae	Tree	Summer	Fruits and	Food Bark sap	Fruits are consumed directly while the sap is consumed as 'Madi/Neera' (Local alcohol).	-
89.	Kharbat/ Kharbati	*Grewia abutilifolia* Vent. ex Juss.	Malvaceae	Shrub	All season	Fruits	Food	Direct consumption of fruits.	-
90.	Kharsheng	*Radermachera xylocarpa*(Roxb.) Roxb. ex K. Schum.	Bignoniaceae	Tree	Monsoon	Fruits	Food	Young pods are boiled to remove bitterness and cooked as vegetable.	-
91.	Khurasani/ Khurasni	*Guizotia abyssinica* (L.f.) Cass.	Compositae	Herb	Summer	Seeds and Leaves	Food	1. Oil is extracted from seeds. 2. Tender leaves steamed and cooked with local masalas as vegetable.	-
92.	Koprya	*Alternanthera sessilis*(L.) R.Br. ex DC.	Amaranthaceae	Herb	Monsoon	Leaves	Food	Leaves are boiled and cooked as vegetable.	-
93.	Vazkand	*Dioscorea hispida* Dennst.	Dioscoreaceae	Climber	Monsoon	Tuber	Food	Tubers are boiled and cooked as vegetable.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
94.	Koshimb/ Koshim/ Kusum	*Schleichera oleosa* (Lour.) Oken.	Sapindaceae	Tree	Winter	Leaves and Seeds	Medicinal	Seed oil is used in vegetable.	Leaves decoction given for vomiting.
95.	Kothambal/ Kothimbir	*Coriandrum sativum* L.	Apiaceae	Herb	All season	Leaves	Food	Leaves cooked as vegetable or consumed directly by adding in the curry or as garnish.	
96.	Kudie/ Kuda/ Kod/ Kudva	*Holarrhena pubescens* Wall. ex G.Don	Apocynaceae	Shrub	Winter	Flowers	Food	Flowers are boiled and cooked as vegetable.	-
97.	Kuharool/ Shid	*Bauhinia racemosa* Lam.	Leguminosae	Tree	Winter	Leaves	Food	Leaves are boiled and cooked as vegetable.	-
98.	Kuli/ Kovalibhaji	*Chlorophytum tuberosum* (Roxb.) Baker	Asparagaceae	Herb	Monsoon	Young leaves	Food	Leaves are boiled and cooked as vegetable.	-
99.	Kumbha	*Careya arborea* Roxb.	Lecythidaceae	Tree	All season	Bark	Medicinal	-	Bark powder is consumed during stomach pain
100.	Kurdu	*Celosia argentea* L.	Amaranthaceae	Herb	Monsoon	Leaves	Food	Young leaves are steamed and cooked with onion and local masalas as vegetable.	-
101.	Kusar	*Jasminum malabaricum* Wight	Oleaceae	Climber	Monsoon	Fruits	Food	Fruits are consumed directly.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
102.	Lokhandi	*Ixora brachiata* Roxb.	Rubiaceae	Tree	All season	Leaves	Medicinal	-	Leaf powder is consumed during cough.
103.	Lundha	*Dioscorea pentaphylla* var. *jacque-montii* (Hook.f.) Prain & Burkill	Dioscorea-ceae	Climber	Monsoon	Young shoots and tubers	Food	1. Tubers are boiled and cooked as vegetable. 2. Young shoots are also boiled and cooked as vegetable.	-
104.	Maswadi	*Ocimum* sps	Lamiaceae	Herb	All season	Leaves	Food	Leaves are used in local sauce preparation	-
105.	Math bhaji/ Getna	*Digera muricata* (L.) Mart.	Amaran-thaceae	Herb	Monsoon	Leaves	Food	Young leaves are steamed and stir fried with onion, garlic and chili to make the vegetable.	-
106.	Mayalu	*Basella alba* L.	Basellaceae	Climber	Monsoon	Leaves	Food	Leaves are specially used to make Fritters. It is also consumed as a vegetable or added in curry preparation.	-
107.	Meki	*Cucumis setosus* Cogn.	Cucurbita-ceae	Climber	Monsoon	Fruits	Food	Raw fruits are consumed directly.	-
108.	Moha/ Moh/ Mohati	*Madhuca longifolia* var. latifolia (Roxb.) A.Chev.	Sapotaceae	Tree	Summer	Seeds and flowers	Food	1. Flowers are cooked and consumed as vegetable. 2. Seeds are crushed for oil which is used during cooking.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
109.	Mokha/ Mukh-pala/ Moka	*Schrebera swietenioides* Roxb.	Oleaceae	Tree	Late Summer	Fruits and Leaves	Food	Young leaves and fruits are boiled and cooked as vegetable.	-
110.	Morvel	*Clematis gouriana* Roxb. ex DC.	Ranuncula-ceae	Climber	Monsoon	Fruits	Food and Medicinal	Leaves boiled and cooked with spices	Fruit extract used in ear ache
111.	Murud sheng/ Aati	*Helicteres isora* L.	Malvaceae	Shrub	Summer	Pods	Medicinal	-	Fruit decoction is used for stomach pain. 1. Crushed powder is consumed with water on scor-pion bite.
112.	Nachani/ Nagli	*Eleusine coracana*(L.) Gaertn.	Poaceae	Herb	Monsoon	Flowers	Food	Grain powder is mixed with water and used for making 'bread'.	-
113.	Nadukali	*Pavetta indica* L.	Rubiaceae	Shrub	Summer	Flowers	Food	Flowers are boiled and cooked as vegetable.	-
114.	Nalbhaji	*Ipomoea aquatica* Forssk.	Convol-vulaceae	Climber	Winter	Leaves and Stem	Food	Leaves and stem are cooked with onion and local masala as vegetable.	-
115.	Nilgiri	*Eucalyptus globulus* Labill.	Myrtaceae	Tree	All season	Leaves	Medicinal	-	Leaf extract used on dental problem and also used in common cold and cough.
116.	Nirgudi	*Vitex negundo* L.	Lamiaceae	Shrub	All season	Leaves	Medicinal	-	Leaf extract used for ear pain.

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
117.	Ova	*Plectranthusamboinicus* (Lour.) Spreng.	Lamiaceae	Herb	All season	Leaves	Food	Leaves used to make Fritters and also added in curries for taste.	-
118.	Palas	*Butea monosperma* (Lam.) Taub.	Leguminosae	Tree	Winter	Flowers	Food and Medicinal	Flowers are used to make vegetable.	Branch decoction is consumed during sore throat.
119.	Papai	*Carica papaya* L.	Caricaceae	Tree	All season	Fruit	Food and Medicinal	Fruits are consumed directly on ripening.	Milky latex is consumed during dental problem.
120.	Papdi	*Holoptelea integrifolia* Planch.	Ulmaceae	Tree	Summer	Seeds	Food and Medicinal	Seeds consumed directly	Bark extract is used for dental diseases.
121.	Raan-Pavata	*Lablab purpureus* (L.) Sweet	Leguminosae	Climber	Winter	Seeds	Food	Seeds are cooked as vegetable.	-
122.	Pave	*Cheilocostusspeciosus* (J.Koenig) C.D.Spech	Costaceae	Herb	Monsoon	Leaves and Stem	Food	Tender leaves and stem are added to curry directly.	-
123.	Pendara/ Pendhar	*Tamilnadia uliginosa* (Retz.) Tirveng. & Sastre	Rubiaceae	Tree	Winter	Fruits	Food (Sold in the market during season)	Young fruits are boiled and cooked for consumption.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
124.	Pimpal	*Ficus religiosa* L.	Moraceae	Tree	All season	Bark	Medicinal	-	Bark powder is mixed with water and consumed during stomach pain.
125.	Ran shegut	*Moringa concanensis* Nimmo	Moringa-ceae	Tree	All season	Bark and Pods	Food and Medicinal	Pods are boiled and cooked with local masala as vegetable.	Bark decoction is consumed during worm infection.
126.	Ran til	*Sesamumi ndicum* L.	Pedaliaceae	Herb	Monsoon	Seeds	Food	The seeds of the plants are crushed to extract edible oil.	-
127.	Ranvanga	*Solanum anguivi* Lam.	Solanaceae	Shrub	Winter	Fruits	Food	Fruits are cooked and stir fried with onion, garlic and chilly.	-
128.	Ratalu/ Ratala	*Ipomoea batatas* (L.) Lam.	Convolvu-laceae	Climber	All season	Tuber	Food (Sold in the market during season)	Tubers are boiled and cooked as vegetable.	-
129.	Ringani/ Ringni	*Solanum xantho-carpum* Schrad. & H. Wendl	Solanaceae	Herb	Monsoon	Fruits	Food	Fruits are cooked and consumed as vegetable	-
130.	Sabar/ Sabarkand	*Euphorbia nerifolia* L.	Euphorbia-ceae	Shrub	All season	Stem	Medicinal	-	Stem decoction is consumed during cough.
131.	Sadhadi/ Aine	*Terminalia tomentosa* Wight & Arn.	Combreta-ceae	Tree	Summer	Fruits	Food	Young fruits are edible.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
132.	Safedkuda	*Holarrhena antidysenterica*(Roth) Wall. ex A.DC.	Apocynaceae	Tree	Summer	Flowers	Food	Flower are boiled and cooked as vegetable.	-
133.	Sag	*Tectona grandis* L.f.	Lamiaceae	Tree	All season	Seeds	Medicinal	-	Powder of seeds is mixed with water and consumed for kidney stone and Renal problems.
134.	Sapud/ Dinda/ Dini	*Leea macrophylla* Roxb. ex Hornem.	Vitaceae	Shrub	Winter	Leaves	Food	Tender leaves are cooked with spices as vegetable.	-
135.	Sarambal	*Justicia procumbens* L.	Acanthaceae	Herb	Monsoon	Leaves	Food	Young leaves boiled and cooked as vegetable.	-
136.	Shevaga/ Shevga/ Sagava/ Shegalu	*Moringa oleifera* Lam.	Moringaceae	Tree	All season	Flowers, Fruits and Leaves	Food	Young leaves, fruits and flowers are cooked and consumed as vegetable.	-
137.	Siral/ Dodka	*Luffa acutangula* (L.) Roxb.	Cucurbitaceae	Climber	Monsoon	Fruit	Food	Fruit cooked as vegetable.	-
138.	Sol	*Cryptocoryne spiralis* (Retz.) Fisch. ex Wydler	Araceae	Herb	Monsoon	Young leaves	Food	Leaves are mixed with Gram flour to make Fritters and then consumed.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
139.	Supali	*Cleome viscosa* L.	Cleomaceae	Herb	Monsoon	Pod	Medicinal	Pods are boiled and cooked as vegetable.	-
140.	Suran	*Amorphophallus paeoniifolius* (Dennst.) Nicolson	Araceae	Herb	Monsoon	Tubers	Food	Tubers are boiled and cooked with local masala as vegetable.	-
141.	Tadgole	*Borrassus flabellifer* L.	Arecaceae	Tree	Summer	Fruits	Food	Fruits are consumed directly.	-
142.	Tagadi/ Tagda/ Taag	*Crotalaria juncea* L.	Leguminosae	Shrub	Monsoon	Flowers	Food	Flowers are boiled and cooked as vegetable.	-
143.	Tambat/ Atrun/ Gugarval	*Flacourtia indica* (Burm.f.) Merr.	Salicaceae	Tree	Monsoon	Fruits	Food	Fruits are consumed directly.	-
144.	Tandala	*Amaranthus tricolor* L.	Amaranthaceae	Herb	Monsoon	Leaves	Food	Leaves are boiled and cooked as vegetable.	-
145.	Tantani	*Lantana camara* L.	Verbenaceae	Shrub	Winter	Fruits	Food	Fruits are consumed directly.	-
146.	Tanvel	*Cocculus hirsutus*(L.) W.Theob.	Menispermaceae	Climber	Monsoon	Leaves	Food	Leaves boiled and cooked in oil as vegetable.	-
147.	Taravata/ Tarota/ Takhata/ Atora	*Senna tora* (L.) Roxb.	Leguminosae	Herb	Monsoon	Leaves and Seeds	Food	1. Young leaves boiled and cooked as vegetable 2. Seeds roasted and powdered to prepare coffee powder and then consumed with boiled water or milk.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
148.	Tehra/ Terda	*Impatiens balsamina* L.	Balsaminaceae	Herb	Monsoon	Young leaves	Food	Young leaves used as vegetable	-
149.	Tembhruni/ Tembhurni/ Tembrun	*Diospyros melanoxylon* Roxb.	Ebenaceae	Tree	Summer	Fruits	Food	Fruits are consumed directly.	-
150.	Tetava/ Tetavi/ Tetu	*Oroxylum indicum* (L.) Kurz	Bignoniaceae	Tree	Early Summer	Young pods and Bark	Food	Young pods are boiled and cooked to make vegetable.	Bark decoction is effective in urinary infection
151.	Tivas	*Desmodium oojeinense* (Roxb.) H.Ohashi	Leguminosae	Tree	All season	Flowers and Bark	Food	Flowers are boiled and cooked as vegetable.	Bark decoction helps in balancing the blood pressure level
152.	Tondali/ Tondval	*Coccinia grandis*(L.) Voigt	Cucurbitaceae	Climber	Monsoon	Fruits	Food and Medicinal	Fruits boiled and cooked as vegetable.	Milky latex is used for mouth ulcer.
153.	Toran	*Ziziphus rugosa* Lam.	Rhamnaceae	Climber	Summer	Fruits	Food	Fruits are consumed directly.	-
154.	Tulas/ Tulasi/ Krushnatulas	*Ocimum tenuiflorum* L.	Lamiaceae	Herb	All season	Leaves	Food and Medicinal	Tulsi leaves are added while making tea to add flavor	Leaf extract is consumed during headaches and coughs.
155.	Udid	*Vigna radiata*(L.) R.Wilczek	Leguminosae	Climber	Monsoon	Seeds	Food	Seeds are boiled with local masalas to prepare curry.	-

Sr. No	Local Name of Species	Scientific Name	Family	Habit	Season of availability	Plant part used	Significance	Recipes (If any)	Medicinal information
156.	Ulashi/ Udasha/ Ulushi	*Dioscorea pentaphylla* L.	Dioscoreaceae	Climber	Monsoon	Tender shoots, leaves and tuber	Food and Medicinal	1. Tubers are boiled and consumed as vegetable. 2. Tender shoots are steamed and stir fried with onion and local masalas as vegetable.	Leaf extract is given as paste during iron deficiency.
157.	Umbar/ Umber/ Athi	*Ficus racemosa* L.	Moraceae	Tree	All season	Fruits	Food	Raw fruits are used to make vegetable while ripe fruits are consumed directly.	-
158.	Usiver	*Cayratia japonica* (Thunb.) Gagnep.	Vitaceae	Climber	Monsoon	Flowers	Food	Flowers are cooked as vegetables.	-
159.	Vad	*Ficus benghalensis* L.	Moraceae	Tree	Monsoon	Fruits	Medicinal	-	Fruits are consumed during stomach pain.
160.	Vaghot/ Vaghat/ Vaghoti/ Ekota/ Kaposhi	*Capparis zeylanica* L.	Capparaceae	Climber	Winter	Fruits	Food	Raw fruits are cooked and consumed as vegetable.	-
161.	Vela karanj	*Derris scandens* (Roxb.) Benth.	Leguminosae	Climber	Monsoon	Tuber	Medicinal	-	Tuber decoction is given to lactating mothers.
162.	Zendu	*Tagetes erecta* L.	Compositae	Herb	All season	Leaves	Medicinal	-	Decoction of leaves is used to cure eye infection

The Presence of Pangolin through Camera Trap Assessment in Ratnagiri District of Northern Western Ghat of Maharashtra, India

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Abstract

Manis crassicaudata (Indian Pangolin), distribution and natural history are poorly known in India. There is much worry regarding the regarding the conservation status of this species across the nation and globe. Pangolins are threatened due to habitat loss and illegal wildlife trade and are highly trafficked mammals in the world. It is essential to understand ecology and distribution of the species and streamline specific species conservation action plan. Sahyadri Nisarga Mitra (SNM) with the support of the forest department and local bodies carried out camera trap assessment to study the presence of the species in Northern Western Ghat of Ratnagiri district, Maharashtra, India. The baseline data derived through local interviews, Traditional knowledge of indigenous communities was used to track species burrows and conduct transect survey. In the present study 36 Camera trap were deployed to document the presence of the species across the region. Camera traps resulted in 1.7% success rate and documented 192 photos and 49 videos of Pangolin activity.

Introduction

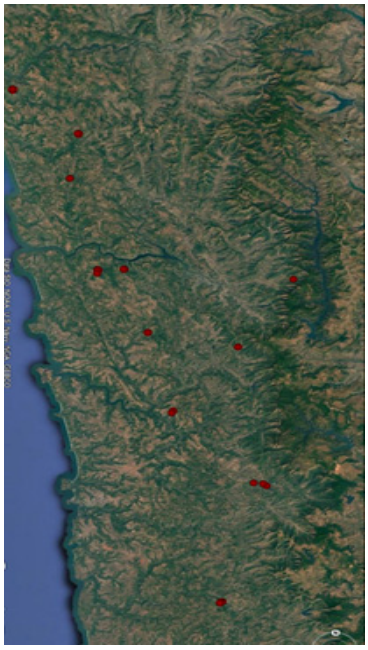
Manis crassicaudata (Indian Pangolin) is very less studied species in wild across the nation due to its shy and nocturnal behavior. Indian Pangolin is listed as an endangered species in IUCN red list (Ballie et.al 2014) and Schedule I species as per the Wildlife Protection Act. Pangolin species are categorized as Appendix I species in the Convention on International Trade in Endangered Species (CITES, 2017). In India major threat to Pangolins include local consumptive use, international trade, and demand for Asian traditional medicine (Challender, 2011; Baillie et al, 2014). Indian Pangolin is distributed throughout Peninsular India, Sri Lanka and Pakistan (Prater, 2005; Mishra and Panda 2012). It was previously found in Bangladesh but is possibly extinct in the region (Baillie et al., 2014). The Pangolins are under threat due to domestic and international demand for live pangolins, skin, scale and bush meat.

Indian Pangolin has body covered with 11-13 rows of sharp overlapping scale (Pocock, 1924), and dorsal and ventral part of the tail is also covered with sharp scale. It is a toothless mammal (Heath 1995) having long sticky tongue to which insects adhere and are swallowed. It plays a vital role in food chain as biological control agent for insects and pest (Robert 1997). Pangolin's nocturnal, solitary and elusive behavior makes them tough to study (Prater 1971) in wild. The distribution and occurrence knowledge is crucial for planning and evaluating conservation strategies (Tobler et al., 2008). Specific species conservation strategies need basic knowledge of the species to streamline conservation action plan in the region. In the present study camera trap assessment of the presence of the species was carried out in the region. Sahyadri Nisarga Mitra team had derived baseline data through local interviews and transect survey in the region. Traditional knowledge of the indigenous communties about species ecology in wild was used to track burrows. We

used Camera trap method to document the presence of the species.

Study Area

The present study was carried out in Ratnagiri district, Maharashtra. Twelve villages across Ratnagiri district were selected to deploy camera trap. The area spans the Northern Western Ghats and Konkan region and has secondary moist and dry deciduous forest in the hilly tracks, scrub forests in the plains and monsoonal herbaceous vegetation on the lateritic plateaus alongwith agricultural lands.



Map 1 : Camera trap locations in Ratnagiri dt.

Methodology

Camera traps were used effectively to detect the presence of rare and nocturnal species of mammal, including pangolins (Bruce et al., 2018). Camera-trap studies have become increasingly popular as technology has improved and costs have decreased (Yasuda, 2004; Tobler et al., 2008). To study the presence of the species in the region data were derived from local community interviews and transect surveys.

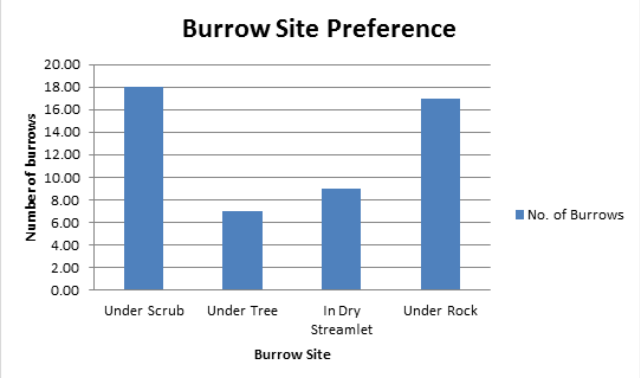
Camera traps were deployed were Cuddeback E2, Cuddeback E3, SpyPoint Solar, Spypoint Force 10, and Local trail camera. A total of 36 Camera trap were installed in 12 villages across the study area. Camera traps were weather proof and durable packed with sensor, white or infrared flashes and compatible settings which made it simpler to deploy camera traps. Camera trap models were set to take two photographs and one 30 seconds videos. To study behavior some used to capture video (Rovero et al. 2013).

Traditional knowledge of indigenous communities was used to track species burrow and indirect signs like scat, and burrows was deployed during the field survey. Camera traps were deployed from January 2019- December 2019 across the study area to document Pangolin presence and behavior in wild. Periodically we visited field to retrieve data and to check battery status, change battery during field visit across the study region.

Result

M. crassicaudata was photographed from 7 village sites and no photographs of the species were obtained from 5 village sites. Undesirable camera trap results from 5 villages do not necessarily indicate absence of the species in the region as indirect signs (Burrow and scat) of the species were seen. Total 192 photographs and 49 videos were obtained during January 2019 – December 2019 (Table 1).

There were other species associated with pangolin burrows including reptiles, small mammals and some ground dwelling and other avian fauna was also photographed. The species photographed were Indian monitor lizard (*V. bengalensis*), Ruddy tailed mongoose (*Herpestes smithii*), Indian grey mongoose (*Herpestes edwardsii*), Small Indian civet (*Viverricula indica*), Asian palm civet (*Paradoxurus hermaphroditus*), and Indian crested porcupine (*Hystrix indica*). Avian fauna are Red spurfoul (*Galloperdix spadicea*), Grey junglefoul (*Gallus sonneratii*), and Puff throated babbler (*Pellorneum ruficeps*).



Graph 1: Burrows site preference of Indian Pangolin

Table 1: Sites where cameras were deployed

Village Site Number	Camera Name	Camera Days	Pangolin Photos	Pangolin Videos	Burrow Type
Site 1	C 2	249.00	0.00	0.00	Under Scrub
	C 7	328.00	10.00	8.00	Under Scrub
	C THT	39.00	2.00	1.00	Under Scrub
	Solar Spy	305.00	0.00	0.00	Under Tree
Site 2	Bambu Cuddy	184.00	0.00	0.00	Under Scrub
	C 11	274.00	6.00	3.00	Under Scrub
	C 13	72.00	2.00	0.00	In Dry Streamlet
	C 17	47.00	0.00	0.00	Under Scrub
	C 32	181.00	0.00	0.00	In Dry Streamlet
	C 39	187.00	13.00	10.00	Under Scrub
	C 41	39.00	0.00	0.00	In Dry Streamlet
	C NEW	110.00	0.00	0.00	Under Scrub
	Force 10	68.00	0.00	0.00	Under Scrub
Site 3	THT CUDDY	20.00	0.00	0.00	Under Rock
Site 4	Black Flash	264.00	0.00	0.00	In Dry Streamlet
	C 18	148.00	6.00	0.00	Under Rock
	C 37	55.00	0.00	0.00	In Dry Streamlet
Site 5	C 3	63.00	0.00	0.00	Under Tree
	C 28	5.00	0.00	0.00	Under Tree
Site 6	C 14	389.00	0.00	0.00	In Dry Streamlet
	C 27	298.00	0.00	0.00	In Dry Streamlet
Site 7	C 17	69.00	0.00	0.00	Under Tree
	Spy Solar	69.00	1.00	1.00	Under Tree
	THT Cuddy	69.00	0.00	0.00	Under Scrub
Site 8	C 24	59.00	2.00	1.00	Under Scrub
Site 9	C 28	11.00	0.00	0.00	Under Tree
	Force 10	11.00	0.00	0.00	Under Tree
Site 10	B 2	39.00	0.00	0.00	Under Rock
	B 3	39.00	2.00	2.00	Under Rock
	C 22	79.00	0.00	0.00	Under Rock
	C 25	55.00	0.00	0.00	Under Rock
	C 32	107.00	1.00	0.00	Under Rock
	C 33	221.00	10.00	1.00	Under Rock
	C 34	260.00	4.00	1.00	Under Rock
	C 35	248.00	13.00	1.00	Under Rock
	C 36	153.00	3.00	0.00	Under Rock
	C NEW	141.00	4.00	1.00	Under Rock

	C NEW 2	38.00	1.00	0.00	Under Rock
	Solar Spy NEW	81.00	2.00	2.00	Under Rock
	THT CUDDY	81.00	6.00	0.00	Under Rock
Site 11	C 17	15.00	0.00	0.00	Under Rock
	C 23	15.00	0.00	0.00	Under Rock
Site 12	Black Flash	43.00	3.00	0.00	Under Scrub
	Browning	14.00	74.00	0.00	In Dry Streamlet
	C 13	29.00	0.00	0.00	Under Scrub
	C 16	14.00	0.00	0.00	Under Scrub
	C 17	14.00	2.00	1.00	Under Scrub
	C 22	29.00	8.00	4.00	In Dry Streamlet
	C 27	14.00	0.00	0.00	Under Scrub
	Solar Spy NEW	14.00	0.00	0.00	Under Scrub
	THT CUDDY	14.00	12.00	6.00	Under Scrub

Discussion

Camera trap methodology is known to be effective to study rare illusive species in a wide range of environments (Cutler and Swann 1999). Camera trap study of a rare and shy nocturnal species is challenging. In this study Pangolins were recorded within 2-30 nights of trapping using 36 camera traps across the study area. In Asia Palawan Pangolin (*M. culionensis*) were recorded soon after camera trap deployed (Marler 2016) and Sunda pangolin (*M. javanica*) were photographed soon after camera trap set up in the region (Lim and Ng 2007). In Sri Lanka pangolin burrows were sighted at elevation in between 75-100 meter (Karawita et al, 2018) and in Pakistan Pangolin restricted in its distribution below 762 meter elevation. In this study pangolin burrows were found at elevation of 13-93 meter Above Sea level and during monsoon Pangolin burrows were found at elevation in between 150-202 meter. In this study pangolin burrows were found under the scrub, under the tree, in dry streamlet with canopy cover, and under the rock. Majority of the burrows were found under the scrub and under the rock (Graph 1) . Indian pangolins are distributed in diverse habitat ranging from hilly area to forest and grassland (Zoological survey of India, 2002). In this study we showed that camera trap methodology is effective to study the presence of the Indian pangolin in the region at different study sites. Camera trap evidence across the region help forest department and SNM to protect species existing in wild.

Table 2 : Indicate Photos and videos obtained in each village site

Village Sites 1	Photos	Videos
Site 1	16	13
Site 2	22	17
Site 3	0	0
Site 4	6	0
Site 5	0	0
Site 6	0	0
Site 7	1	1
Site 8	2	1
Site 9	0	0
Site 10	46	8
Site 11	0	0
Site 12	99	9

Acknowledgment

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Documentation of Riparian Biodiversity of an Urban River Stretch – A Citizen's Initiative

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Abstract

Rivers in urban areas are facing multidimensional threats ranging from untreated sewage discharge, garbage and debris dumping, developmental projects to illegal encroachment on banks. Still few river stretches in urban areas harbor rich riparian biodiversity. Such areas need protection to avoid further degradation. These river stretches serve as ideal river ecosystem adding to ecological value of the area. The present study deals with documentation of riparian biodiversity of river stretch in Pune, Maharashtra. This area is a confluence zone of Mula and Ram rivers. River undergoes ecological processes during her flow and flood regimes. This adds to making the region not only rich in biodiversity but acts like a sponge for flooding water, temperature control, ground water recharge and creating green lungs for local region. Ecological processes include formation of an island, braiding of channel, rocky outcrops, riffles and pools etc. All this together create specific habitats for diverse species. This river stretch is part of flood plain area and has presence of live springs. The objective of the study was to document the floral and avian biodiversity of the riparian area with help of public participation with a view of protecting this area. During the study we have recorded about 70 floral species and 60 avian species at this riparian zone. The riverbank harbours a thick patch of typical riparian vegetation comprising of Pongamia pinnata, Syzygium cumini, Syzygium heyneanum, Salix tetrasperma and Ficus racemosa. Regular monitoring and observations at the river stretch are being carried out by a group of active citizens who are members of Jeevitnadi Living River Foundation. This vigilance, year round monitoring and documentation is helping in protecting the river stretch. Some major threats and stresses faced by this serene riparian forest are sewage discharge, debris dumping, encroachment and developmental projects. Point and non-point sources of pollution include release of untreated sewage from Sewage Treatment Plant situated at confluence, discharge of sewage and waste dumping by slum dwellers situated along Ram River.

Introduction

The confluence of Mula and Ram rivers located at New Aundh-Baner link road harbors a typical riparian ecosystem showing positive ecological indicators (see Fig. 1). The river stretch is approximately 1 km with riparian area of 70,635.58 m².

The Area has riparian tree species like Karanj,

Fig. 1 : Google earth image showing the Riparian Forest

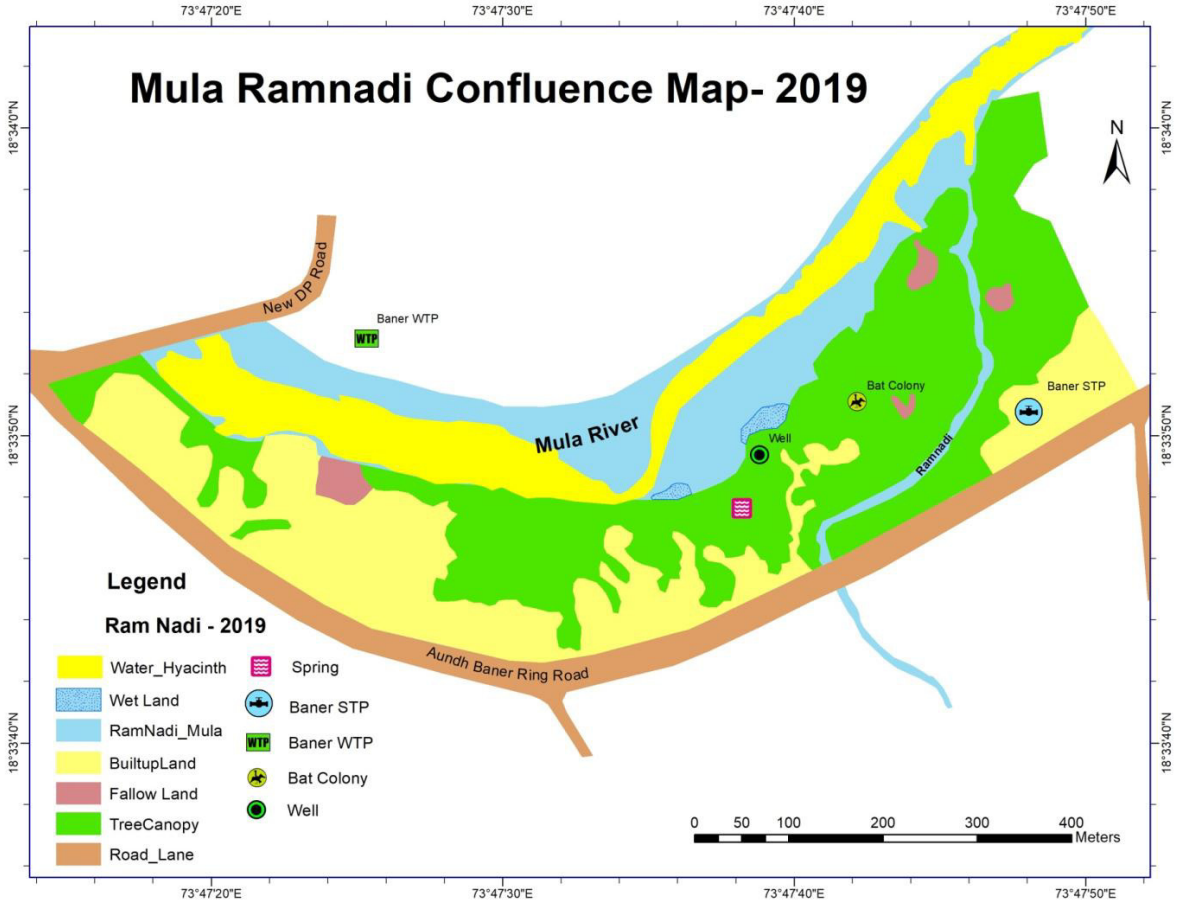


Fig. 2

Jambhul, Umbar. Both the river banks have dense cover of vegetation with variety of trees, shrubs, herbs and grass species. Such three-layered vegetation along with presence of lianas, mushrooms, lichens indicate a rich riparian ecosystem. They provide an evergreen character with shady areas in that patch of river, providing habitat for aquatic biodiversity.

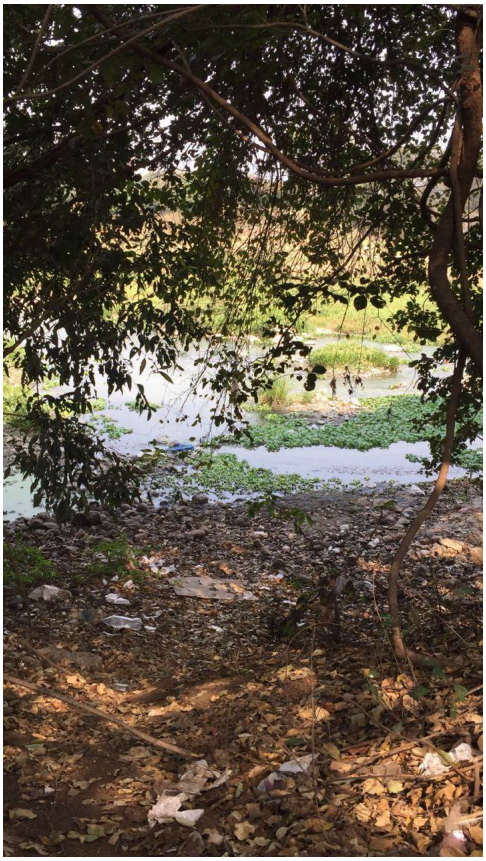
Biodiversity documentation work started in August 2017 (under Adopt a Stretch program of Jeevitnadi)

This stretch of confluence is very serene with shallow and broad riverbed rich in microhabitats like islands, pools, puddles, few open patches and wetlands on the banks. Each habitat shows its associated flora and fauna. Deep black soil deposits along the bank with good moisture content were also observed. The stretch has some live streams, natural drains and a well showing its hydrological importance (see Fig. 2).

River bank is bordered by typical riparian vegetation which includes *Pongamia pinnata* (Karanj)-*Syzygium sp.* (Jambhul, Panjambhul) associated with *Ficus racemosa* (Umbar). Presence of typical riparian tree species, Walunj (*Salix tetrasperma*) along with *Syzygium heyneanum* (Pan Jambhul) in good number is most important feature of this riparian forest.

The bank vegetation also has dense canopy cover of trees like *Mitragyna parviflora* (kalam), *Ficus hispida* (Dhedumber/Kalumbar), *Tamarindus indica* (Chinch), *Mangifera indica* (Amba) with abundant undergrowth of *Glycosmis pentaphylla* and occasionally grown *Phyllanthus reticulatus* (Nilumbi). Fully grown Liana of *Combratum ovalifolium* (Piluk) on *Ficus racemosa* (Audumbar) tree is added beauty of the place and indicates the presence of old growth vegetation with good ecological value. A detailed list of vegetation is attached in Table 1.

In River channel, pools supports abundant growth of river crinum lily (*Crinum viviparum*), which is one of the important indigenous aquatic floral species. Its presence indicates better water quality and presence of suitable habitat. At Some places *Typha angustifolia* (Pankanis) and *Cyperus* sps (Lavhale) are found growing in clusters creating good habitats for nesting/roosting of water birds. Islands in the river show dense cover of grass species along with typical wetland vegetation like *Persicaria glabra* (Sheral) and *Cyperus* sps. Water hyacinth growth is seen occasionally near bank



Riparian area

Liana (woody climber) in riparian area

and islands.

The area has also been surveyed for documenting bird diversity. Sixty two bird species are recorded with maximum number of Indian spot-billed duck and Little cormorant. Other water birds seen include Painted Stork, Grey Heron, Purple Heron, Indian Pond-Heron, Common Sandpiper, Common Kingfisher, White-throated Kingfisher, Pied Kingfisher etc. (see Table 2). Presence of pied kingfisher indicates good water quality with presence of fish, as the bird needs clear water for fishing. Black Kite, Red-wattled Lapwing, Greater Coucal, Common Hawk-Cuckoo, Common Iora, House Crow, Large-billed Crow, Common Tailorbird, Purple Sunbird, House Sparrow are the terrestrial bird species recorded there. Presence of diverse butterfly life also underlines significance of the site. Presence of Sandpipers indicate good health of wading habitat at the site. Also, occurrence of diverse species of Herons, Egrets, Kingfishers, Wagtails, Stork confirm this site as a good wetland ecosystem which needs urgent protection.

Black-headed ibis, Painted Stork, River Tern are Near threatened found here alongwith Woolly necked stork which is Vulneable.

Butterfly species like Plain Tiger, Striped Tiger, Danaid Eggfly, Lime butterfly, Common Mormon, Common Jezebel, Yellow Orange Tip, Common Crow etc have been reported from this area.

Presence of a colony of fruit bats which are important pollinators, indicates a good habitat zone. All this flora-fauna support river ecosystem and increases her richness.

Thus this river confluence stretch is very important for its dense riparian vegetation, associated fauna and hyphoric zone created by it.

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River Crinum lily

Flowering of Glycosmis pentaphylla

Karanj Tree

Riparian area

Table 1 : List of plant species seen at Ram-Mula Confluence

Sr. no.	Botanical name	Common name	Family
1.	*Acacia nilotica* (L.) Delile	*Babhul*	Leguminosae
2.	*Acacia* sp.	-	Leguminosae
3.	*Albizia lebbeck* (L.) Benth.	*Shirish*	Leguminosae
4.	*Alternanthera ficoidea* (L.) Sm.	*Chobuk kata*	Amaranthaceae
5.	*Alternanthera sessilis* (L.) R.Br. ex DC.	*Kanchari*	Amaranthaceae
6.	*Annona reticulata* L.	*Ramphal*	Annonaceae
7.	*Argemone mexicana* L.	*Bilayat, Pivla Dhotra*	Papaveraceae
8.	*Artemisia nilagirica* (C.B. Cl.) Pamp.	-	Compositae
9.	*Asclepias curassavica* L.	*Haldi-kunku*	Apocynaceae
10.	*Azadirachta indica* A.Juss.	*Neem*	Meliaceae
11.	*Chromolaena odorata* (L.) R. M. King & H.Rob.	*Ranmari*	Compositae
12.	*Chrozophora tinctoria* (L.) A.Juss.	*Dyer's Litmus*	Euphorbiaceae
13.	*Clitoria ternatea* L.	*Gokarna*	Leguminosae
14.	*Coccinia grandis* (L.) Voigt	*Tondali*	Cucurbitaceae
15.	*Cocculus hirsutus* (L.) W.Theob.	*Vasanvel*	Menispermaceae
16.	*Cocos nucifera* L.	*Naral*	Arecaceae
17.	*Colocasia* sp.	*Alu*	Araceae
18.	*Combretum ovalifolium* Roxb.	*Piluk*	Combretaceae
19.	*Cordia dichotoma* G.Forst.	*Bhokar*	Boraginaceae
20.	*Crinum viviparum* (Lam.) R.Ansari & V.J.Nair	*River lily*	Amaryllidaceae
21.	*Cryptolepis dubia* (Burm.f.) M. R. Almeida	*Kavli*	Apocynaceae
22.	*Cyperus* sp.	*Lavhale*	Cyparaceae
23.	*Dendrophthoe* sp.	*Bandgul*	Loranthaceae
24.	*Dioscorea* sp.	*Varhkand*	Dioscoreaceae
25.	*Eichhornia crassipes* (Mart.) Solms	*Eichhornia, Jalkumbhi*	Pontederiaceae
26.	*Eucalyptus* sp.	*Nilgiri*	Myrtaceae
27.	*Ficus hispida* L.f.	*Bhuiumber*	Moraceae
28.	*Ficus racemosa* L.	*Umber*	Moraceae
29.	*Glycosmis pentaphylla* (Retz.) DC.	*Kirmira*	Rutaceae
30.	*Grewia* sp.	*Phalsa*	Malvaceae
31.	*Haplanthodes verticillatus* (Roxb.) R. B. Majumdar	*Zankara*	Acanthaceae
32.	*Holoptelia integrifolia* (Roxb.) Planch.	*Vavla, Papdi*	Ulmaceae

Sr. no.	Botanical name	Common name	Family
33.	*Ipomoea quamoclit* L.	*Ganeshvel*	Convolvulaceae
34.	*Ipomoea* sp.	-	Convolvulaceae
35.	*Croton bonplandianus* Baill.	-	Eupborbiaceae
36.	*Leonotis nepetifolia* (L.) R.Br.	*Deepmal*	Lamiaceae
37.	*Limonia acidissima* Groff	*Kavath*	Rutaceae
38.	*Madhuca longifolia var. latifolia* (Roxb.) A. Chev.	*Madhuka*	Sapotaceae
39.	*Mangifera indica* L.	*Amba*	Anacardiaceae
40.	*Manilkara zapota* (L.) P.Royen	*Chikku*	Sapotaceae
41.	*Mitragyna parvifolia* (Roxb.) Korth.	*Kalam*	Rubiaceae
42.	*Parthenium hysterophorus* L.	*Congress grass*	Compositae
43.	*Passiflora foetida* L.	*Passiflora, Vel-ghani*	Passifloraceae
44.	*Persicaria glabra* (Willd.) M.Gómez	*Sheral*	Polygonaceae
45.	*Phoenix sylvestris* (L.) Roxb.	*Shindi*	Arecaceae
46.	*Phyllanthus reticulatus* Poir.	*Panjuli, Nilumbi*	Phyllanthaceae
47.	*Pistia stratiotes* L.	*Pistia*	Araceae
48.	*Plumbago zeylanica* L.	*Chitrak*	Plumbaginaceae
49.	*Polyalthia longifolia* (Sonn.) Thwaites	*Khota Ashok*	Annonaceae
50.	*Pongamia pinnata* (L.) Pierre	*Karanj*	Leguminosae
51.	*Salix tetrasperma* Roxb.	*Valunj*	Salicaceae
52.	*Sida acuta* Burm.f.	*Bala*	Malvaceae
53.	*Sida cordata* (Burm.f.) Borss.Waalk.	*Bhumibala*	Malvaceae
54.	*Sida rhombifolia* L.	*Bala*	Malvaceae
55.	*Solanum viarum* Dunal	*Ranwangi*	Solanaceae
56.	*Syzygium cumini* (L.) Skeels	*Jambhul*	Myrtaceae
57.	*Syzygium heyneanum* (Duthie) Gamble	*Pan Jambhul*	Myrtaceae
58.	*Syzygium rubicundum* Wight & Arn.	*Lendi Jambhul*	Myrtaceae
59.	*Tamarindus indica* L.	*Chinch*	Leguminosae
60.	*Tectona grandis* L.f.	*Sag*	Lamiaceae
61.	*Tinospora cordifolia* (Willd.) Miers	*Gulvel*	Menispermaceae
62.	*Urena lobata* L.	*Mahabala*	Malvaceae
63.	*Withania somnifera* Dunal	*Ashwagandha*	Solanaceae
64.	*Ziziphus oenopolia* (L.) Mill.	*Ran bor*	Rhamnaceae

Table 2 : List of bird species seen at Ram-Mula Confluence

Sr No	Common Name	Scientific Name
1	Indian Spot-billed Duck	*Anas poecilorhyncha*
2	Little Cormorant	*Microcarbo niger*
3	Painted Stork	*Mycteria leucocephala*
4	Wooly necked Stork	*Ciconia episcopus*
5	Indian Pond Heron	*Ardeola grayi*
6	Grey Heron	*Ardea cinerea jouyi*
7	Purple Heron	*Ardea purpurea*
8	Common Sandpiper	*Actitis hypoleucos*
9	Common Kingfisher	*Alcedo atthis*
10	White-throated Kingfisher	*Halcyon smyrnensis*
11	Pied Kingfisher	*Ceryle rudis*
12	Black Kite	*Milvus migrans*
13	Red-wattled Lapwing	*Vanellus indicus*
14	Greater Coucal	*Centropus sinensis*
15	Common Hawk Cuckoo	*Hierococcyx varius*
16	House Crow	*Corvus splendens*
17	Large-billed Crow	*Corvus macrorhynchos*
18	Common Iora	*Aegithina tiphia*
19	Common Tailorbird	*Orthotomus sutorius*
20	Purple Sunbird	*Cinnyris asiaticus*
21	Purple-rumped Sunbird	*Leptocoma zeylonica*
22	House Sparrow	*Passer domesticus*
23	Ruddy Shelduck	*Tadorna ferruginea*
24	White-breasted Waterhen	*Amaurornis phoenicurus*
25	Common Moorhen	*Gallinula chloropus*
26	Purple Moorhen	*Porphyrio porphyrio*
27	River Tern	*Sterna aurantia*
28	Little Grebe	*Tachybaptus ruficollis*
29	Little Egret	*Egretta garzetta*
30	Intermediate Egret	*Ardea intermedia*
31	Cattle Egret	*Bubulcus ibis*
32	Black crowned Night Heron	*Nycticorax nycticorax*

Sr No	Common Name	Scientific Name
33	Black-headed Ibis	*Threskiornis melanocephalus*
34	Glossy Ibis	*Plegadis falcinellus*
35	Eurasian Spoonbill	*Platalea leucorodia*
36	Rufous Treepie	*Dendrocitta vagabunda*
37	Eurasian Golden Oriole	*Oriolus oriolus*
38	Small Minivet	*Pericrocotus cinnamomeus*
39	Black Drongo	*Dicrurus macrocercus*
40	Oriental Magpie Robin	*Copsychus saularis*
41	Indian Robin	*Saxicoloides fulicatus*
42	Pied Bushchat	*Saxicola caprata*
43	Common Myna	*Acridotheres tristis*
44	Brahminy Starling	*Sturnia pagodarum*
45	Cinereous Tit	*Parus major stupae*
46	Wire-tailed Swallow	*Hirundo smithii*
47	Barn Swallow	*Hirundo rustica*
48	Red-vented Bulbul	*Pycnonotus cafer*
49	Red-wishkered Bulbul	*Pycnonotus jocosus*
50	Ashy Prinia	*Prinia socialis*
51	Coppersmith Barbet	*Megalaima haemacephala*
52	Common Grey Hornbill	*Ocyceros birostris*
53	Grey-bellied Cuckoo	*Cacomantis passerinus*
54	Rose-ringed Parakeet	*Psittacula krameri*
55	Alexandrine Parakeet	*Psittacula eupatria*
56	Grey Wagtail	*Motacilla cinerea*
57	White Wagtail	*Motacilla alba*
58	White-browed Wagtail	*Motacilla maderaspatensis*
59	Eurasian Coot	*Fulica atra*
60	White-spotted Fantail	*Rhipidura albicollis*
61	Asian Koel	*Eudynamys scolopaceus*
62	Green Bee eater	*Merops orientalis*

Butterfly Diversity of the ARAI Hills

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Introduction

Pune, a region in the Northern Western Ghats of India is popularly known as the City of Hills. These hills are the green lungs of the city acting as an essential oxygen reservoir. Some of the hills in the Pune region include- Taljai hill, Baner hill, Warje hill, Mahatma hill and the well-known ARAI Hill.

ARAI Hill/Vetal Tekdi is a hillock situated in the heart of urban Pune. Vetal Hill is a part of Bhamburda Van Vihar located on the western side of Pune Municipal Corporation within the city limits. Vetal Tekdi is prominent and is visible from Pashan, Paud Road, Chattushrungi and other parts of the city. The geographical area is 18º 30′ to 18º 32′ N and 73º 49′ to 73º 52′ E covering an area of 10.5 square kilometres (4.1 sq mi). The hill shares same climatic conditions with that of the Pune city. Summers reach nearly 45 degrees while in winters, the temperature drops upto 8 degrees, covering the hill with fog. (Source- Wikipedia)

The hill supports a diverse array of biodiversity ranging from massive raptors to tiniest creatures like ants. One of the most interesting and diverse group of lifeforms which reside on the hill is of the butterflies. Butterflies have been depicted as significant bio-indicator species owing to their sensitivity to slightest change in environmental factors. Also, these are lower members of the intricate food chain. These are fed upon by various birds, reptiles and other insects. The study of butterflies relate closely with that of the availability of host and nectaring plants in that space. The landscape of ARAI hill is predominantly covered by scrubland species of *Casia, Acacia,* along with blooms of the invasive *Lantana* species. This document deals with the monitoring of butterflies on the ARAI hill. This would promote butterfly studies and ecology, especially in the urban areas of Pune. The only previous publication, Kunte (2000-01) didn't have any consideration while studying this area. Therefore it would be a new set of information coming from Pune city.

Methodology

Butterfly monitoring makes it easier to track their distribution and population changes on a local scale as well as a large region.

The scientific documentation of butterflies on ARAI hill began in the year 2017 by Rajat Joshi and Advait Chaudhari. Butterflies were documented covering 6 different seasons across the span of 2 years. For the interpretation of collected data the year was divided into six seasons as per Kunte (1997). These seasons are (i) Spring(Sp) - February and March; (ii) Summer (Su) - April and May; (iii) Early monsoon (Em) - June and July; (iv) Post monsoon(Pm) - August and September; (v) Early winter (Ew) - October and November and (vi) Late winter (Lw) - December and January. Butterflies of Pune group, a WhatsApp group made in 2018 selected the ARAI hill as a butterflying spot where they arranged butterfly walks once in a fortnight for 3 years to document butterflies. Dr. Milind Bhakhare, an ophthalmologist and a stalwart of butterflying guided the members in the initial stages of the walk. Since then, several butterfly enthusiasts have frequently started to visit the hill.

Conditions

Sunny days with clear skies from 9 am to 11 am were preferred for documentation.

Documentation

Line transect method was used for monitoring butterflies. There are 6 major transect routes for butterfly

monitoring, namely

1) MIT side slope of hill
2) Grasslands behind and around the quarry
3) Kanchan Lane
4) Gokhale nagar side (Bhamburda Van vibhag)
5) Paud road and
6) Panchavati side of the hill.

To make this process easier these, major transects were divided into several smaller transects of 500m. Areas of 10m on either sides were taken into consideration.

Single species count

Some rare species occurred on remote sites, away from the Transect location. Such species have high conservational values. To document such species single species counts were taken during their flight period.

Equipments used

Equipments like Digital Cameras for photographic records and on-field guides : M. Bhakhare and H. Ogale,(2018), Butterflies of Western Ghats and Peter Smetacek, (2017), A Naturalist's guide to Butterflies of India.

Observations

The documented species of butterflies were classified in 5 families belonging to the order Lepidoptera. The common names are adopted from Evans (1932) and Winter Blythe (1957). For scientific nomenclature, Gaonkar (1996) is refered. The observations and further calculations are based on Tiple (2012).

Results and discussion

The Table 1 shows that, out of 87 species, majority of the species residing on the hill belong to Lycaenidae family followed by the nymphalids. The family wise relative occurrence of butterflies is shown in Table 2 and in Fig. 1. The grassland habitat along with the local host plants like *Acacia, Casia, Capparis* and *Cadaba* sp seem to be a very suitable habitats to these butterflies. Butterflies have distinct flight period and occur with a very short seasonal peak remaining absent or rare in the rest of the year. Some species occur throughout the year with a short population peak in a specific season, and some species occur only for a few months, such as the Albatross and Crimson tips. (Kunte, 2000-01). The Indian Plains Blue Royal was sighted for the first time in Pune in the year 2020, which is an addition to Kunte (2000-01) checklist on Butterflies of Pune.

Conclusion

This exercise to document butterflies of ARAI hill complex will contribute to central data set. This will partly be useful to assess the ecological values of ARAI hill complex.

Suggestion

The study proposed would inculcate scientists from all the backgrounds to exchange their ideas and work together to save this heritage on the hill threatened by anthropogenic disturbances in the near future

Acknowledgements

We would like to thank Anuj Khare for supporting this study. The members of Pune butterfly group and all the butterfly enthusiasts who documented these winged jewels on the hill.

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Table 1 : Checklist of the butterflies with their seasonal pattern

Sr. No	Family	Scientific Name	Common Name	Seasons Observed
1	Papilionidae	*Graphium agamemnon*	Tailed Jay	Sp, Su, Em, Pm, Ew, Lw
2	Papilionidae	*Graphium doson*	Common Jay	Em, Pm
3	Papilionidae	*Papilio demoleus*	Lime Swallowtail	Sp, Su, Em, Pm, Ew, Lw
4	Papilionidae	*Papilio polytes*	Common Mormon	Sp, Su, Em, Pm, Ew, Lw
5	Papilionidae	*Papilio polymnestor*	Blue Mormon	Sp, Em, Pm
6	Papilionidae	*Pachliopta aristolochiae*	Common Rose	Pm
7	Pieridae	*Eurema hecabe*	Common Grass Yellow	Sp, Su, Em, Pm, Ew, Lw
8	Pieridae	*Eurema blanda*	Three-Spot Grass Yellow	Pm
9	Pieridae	*Eurema laeta*	Spotless Grass Yellow	Ew, Lw
10	Pieridae	*Eurema brigitta*	Small Grass Yellow	Pm, Lw
11	Pieridae	*Catopsilia pomona*	Common Emigrant	Sp, Su, Em, Pm, Ew, Lw
12	Pieridae	*Catopsilia pyranthe*	Mottled Emigrant	Sp, Su,Em, Pm, Ew,Lw
13	Pieridae	*Ixias marianne*	White-Orange Tip	Em, Pm, Ew, Lw
14	Pieridae	*Pareronia hippia*	Indian Wanderer	Em, Pm, Ew, Lw
15	Pieridae	*Belenois aurota*	Indian Pioneer	Sp, Su, Em, Pm
16	Pieridae	*Leptosis nina*	Pysche	Sp, Ew, Lw,
17	Pieridae	*Appias libythea*	Stripped Albatross	Pm
18	Pieridae	*Cepora nerissa*	Common Gull	Su, Em, Pm, Ew
19	Pieridae	*Colotis danae*	Crimson Tip	Em, Pm
20	Pieridae	*Colotis aurora*	Plain Orange Tip	Pm
21	Pieridae	*Colotis etrida*	Little Orange Tip	Pm
22	Pieridae	*Ixias pyrene*	Yellow-Orange Tip	Pm
23	Nymphalidae	*Euploea core*	Common Crow	Sp, Su, Em, Pm, Ew, Lw
24	Nymphalidae	*Danaus genutia*	Plain Tiger	Sp, Su, Em, Pm, Ew, Lw
25	Nymphalidae	*Danaus chrysippus*	Stripped Tiger	Sp, Em, Pm, Ew, Lw
26	Nymphalidae	*Tirumala limniace*	Blue Tiger	Sp, Em, Pm, Ew, Lw
27	Nymphalidae	*Parantica aglea*	Glassy Tiger	Sp, Em, Pm, Ew, Lw
28	Nymphalidae	*Acraea terpsicore*	Tawny Coster	Sp, Su, Em, Pm, Ew, Lw
29	Nymphalidae	*Phalanta phalantha*	Common Leopard	Em, Pm, Ew, Lw
30	Nymphalidae	*Neptis hylas*	Common Sailer	Em, Pm, Ew
31	Nymphalidae	*Ariadne merione*	Common Castor	Sp, Su, Em, Pm, Ew, Lw
32	Nymphalidae	*Hypolimnas bolina*	Great Eggfly	Em, Pm, Ew, Lw

Sr. No	Family	Scientific Name	Common Name	Seasons Observed
33	Nymphalidae	*Hypolimnas misippus*	Danaid Eggfly	Sp, Su, Em, Pm, Ew, Lw
34	Nymphalidae	*Junonia atlites*	Grey Pansy	Pm, Ew
35	Nymphalidae	*Junonia lemonias*	Lemon Pansy	Sp, Su, Em, Pm, Ew, Lw
36	Nymphalidae	*Junonia orithya*	Blue Pansy	Em, Pm, Ew, Lw
37	Nymphalidae	*Junonia iphita*	Chocolate Pansy	Sp, Su, Em, Pm, Ew, Lw
38	Nymphalidae	*Junonia hierta*	Yellow Pansy	Em, Pm, Ew
39	Nymphalidae	*Junonia almana*	Peacock Pansy	Pm, Ew
40	Nymphalidae	*Melanitis leda*	Common Evening Brown	Sp, Su, Em, Pm, Ew, Lw
41	Nymphalidae	*Mycalesis perseus*	Common Bushbrown	Em, Pm, Ew
42	Nymphalidae	*Mycalesis mineus*	Dark Banded Bushbrown	Em, Pm, Ew
43	Nymphalidae	*Ypthima asterope*	Common Three-Ring	Sp, Em, Pm, Ew, lLw
44	Nymphalidae	*Lethe rohria*	Common Treebrown	Em, Pm, Ew
45	Nymphalidae	*Ypthima baldus*	Common Five-Ring	Sp, Em, Pm, Ew, lLw
46	Lycaenidae	*Spalgis epius*	Apefly	Pm, Ew
47	Lycaenidae	*Rapala manea*	Slate Flash	Em, Pm
48	Lycaenidae	*Rapala iarbus*	Red Flash	Em, Pm
49	Lycaenidae	*Talicada nyseus*	Red Pierrot	Sp, Em, Pm
50	Lycaenidae	*Castalius rosimon*	Common Pierrot	Pm, Ew, Lw
51	Lycaenidae	*Caleta decidia*	Angled Pierrot	Em, Pm
52	Lycaenidae	*Acytolepis puspa*	Common Hedge Blue	Pm, Ew
53	Lycaenidae	*Chilades pandava*	Plains Cupid	Em, Pm, Ew
54	Lycaenidae	*Leptotes plinius*	Zebra Blue	Sp, Su, Em, Pm, Ew, Lw
55	Lycaenidae	*Chilades parrhasius*	Small Cupid	Sp, Em, Pm
56	Lycaenidae	*Chilades lajus*	Lime Blue	Sp, Su, Pm, Ew
57	Lycaenidae	*Euchrysops cnejus*	Gram Blue	Sp, Pm, Ew, Lw
58	Lycaenidae	*Lampides boeticus*	Pea Blue	Sp, Pm, Ew, Lw
59	Lycaenidae	*Zizeeria karsandra*	Dark Grass Blue	Sp, Pm, Ew, Lw
60	Lycaenidae	*Zizina otis*	Lesser Grass Blue	Sp, Pm, Ew, Lw
61	Lycaenidae	*Pseudozizeeria maha*	Pale Grass Blue	Sp, Pm, Ew, Lw
62	Lycaenidae	*Zizula hylax*	Tiny Grass Blue	Sp, Ew, Lw
63	Lycaenidae	*Jamides celeno*	Common Cerulean	Sp, Su, Em, Pm, Ew, Lw
64	Lycaenidae	*Prosotas nora*	Common Lineblue	Sp, Ew, Lw
65	Lycaenidae	*Prosotas dubiosa*	Tailless Lineblue	Sp, Ew, Lw

Sr. No	Family	Scientific Name	Common Name	Seasons Observed
66	Lycaenidae	*Freyeria putli*	Grass Jewel	Ew, Lw
67	Lycaenidae	*Jamides bochus*	Dark Cerulean	Em, Pm
68	Lycaenidae	*Spindasis elima*	Scarce Shot Silverline	Em, Pm
69	Lycaenidae	*Spindasis schistacea*	Plumbeous Silverline	Em, Pm
70	Lycaenidae	*Spindasis icits*	Common Shot Silverline	Em, Pm
71	Lycaenidae	*Spindasis vulcanus*	Common Silverline	Em, Pm
72	Lycaenidae	*Azanus uranas*	Dull Babul Blue	Em, Pm
73	Lycaenidae	*Azanus jesous*	African Babul Blue	Em, Pm
74	Lycaenidae	*Megisba malaya*	Malayan	Pm
75	Lycaenidae	*Anthene lycaenina*	Pointed ciliate blue	Pm, Ew
76	Lycaenidae	*Azanus ubdalus*	Bright Babul Blue	Em, Pm
77	Lycaenidae	*Tejuria*	Plains Blue Royal	Su
78	Lycaenidae	*Tejuria cippus*	Peacock Royal	Sp, Su
79	Lycaenidae	*Jamides alecto*	Metallic Cerulean	Em, Pm
80	Hesperiidae	*Hasora chromus*	Common Banded Awl	Pm
81	Hesperiidae	*Borbo cinnara*	Rice Swift	Pm, Ew
82	Hesperiidae	*Pelopidas mathias*	Small Branded Swift	Pm, Ew
83	Hesperiidae	*Telicota bambusae*	Palm Dart	Pm
84	Hesperiidae	*Matapa aria*	Common Red eye	Pm, Ew
85	Hesperiidae	*Udaspes folus*	Grass Demon	Pm
86	Hesperiidae	*Sarangesa dasahara*	Small Spotted Flat	Pm
87	Riodinidae	*Abisara bifisciata*	Double Banded Judy	Pm

Table 2 : Number of Butterfly Species according to relative occurance

Sr. no	Name of the family	No. of species	Relative occurrence No. of species/ total species * 100
1	Papilionidae	6	6.9
2	Pieridae	16	18.4
3	Nymphalidae	23	26.4
4	Lycaenidae	34	39.1
5	Hesperiidae	7	8.1
6	Riodinidae	1	1.1
		Total – 87	100%

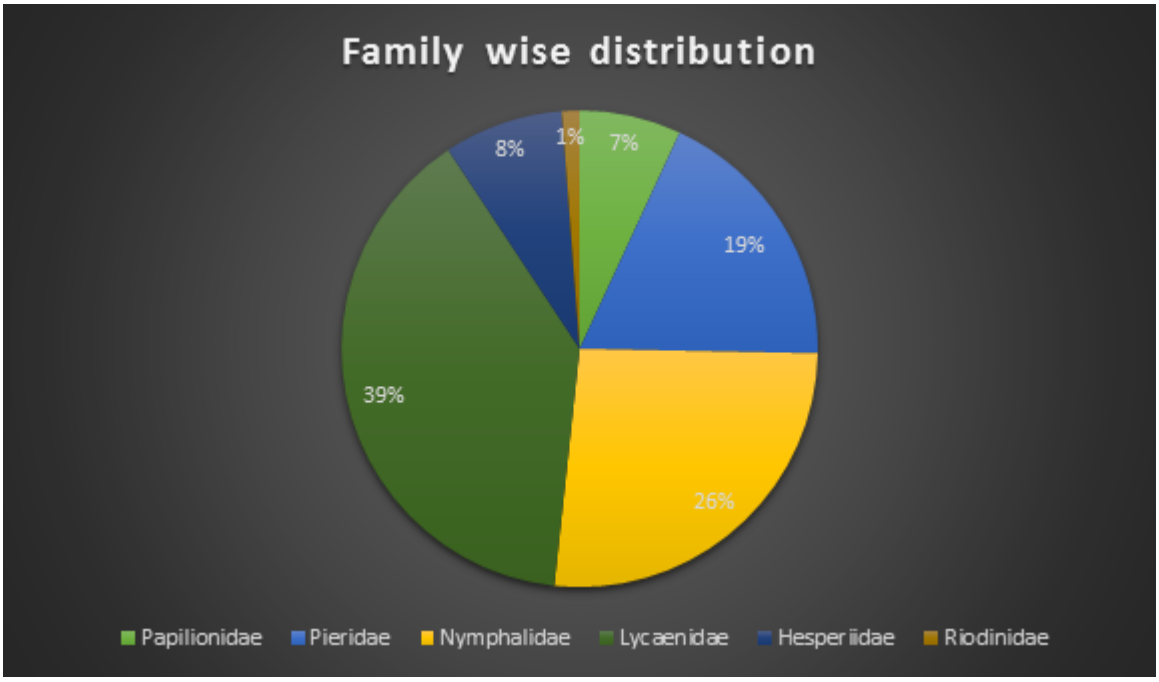
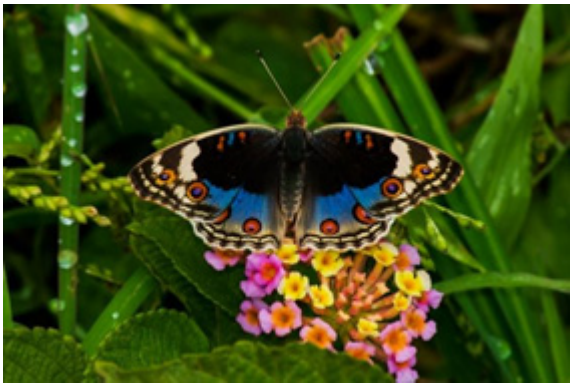


Fig. 1



Blue Pansy

Red Flash

Common Leopard

Indian Common short Silver-line

Peacock Pansy

Yellow Pansy

Common Sailer

Common Wanderer

The larval host plants of the surveyed butterflies were identified throughout the landscape of the hill. They are listed as follows :

Table 3 : List of Host Plants

Sr. No	Scientific name	Common Name	Host plant of -
1	*Acacia catechu*	Babul/Khair	Babul blues, Silverlines, Flashes, Line blues
2	*Capparis sp.*		Orange tips, Crimson Tips, Gulls, Pioneers
3	*Cadaba fruticosa*		Orange tips, Crimson Tips, Gulls, Pioneers, Silverlines.
4	*Wattakaka volubilis*		Blue Tiger
5	*Cassia tora*	Takla	Emigrants, Grass yellows
6	*Lantana camara*	Tantani	Slate Flash
7	*Calotropis gigantea*	Rui	Plain Tiger, Stripped Tiger
8	*Poaceae species 1*	Gavat	Evening brown, Bush browns.

Ecological Guidelines and Recommendations for Mula-Mutha Riverfront Development

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Dr. Gurudas Nulkar is a professor at Symbiosis International University and Ecological Society, Pune. He is the Endeavour Fellow of government of Australia. His research interests lie in alternatives to the current economic system, for sustainable development.

Abstract

This paper is a case of urban river Mutha for ecological management.Over the past few decades, condition of river Mutha has deteriorated considerably. The present situation shows less of fresh water flow and lot of sewage water addition,waste dumping and foul smelling water flow. The fresh water contribution by base flow to the main stream is very negligible. The only source of fresh water is sporadic water release from Khadakwasala dam. It is irregular and in small proportion to support ecosystem functioning of the river Mutha.There is a of public debate regarding improvement in the river's condition and to correct its root cause. The disruption in the river's ecosystem is basically by human interventions. The study appeals for interdisciplinary approach with a view of environmental governance and management to solve river related problems. The focus of this study is to assess environmental impact when the river related projects being planned by Municipal authorities. The study included survey of physical changes by human interventions, in the river Mutha channel ,banks and modification of habitats hampering aquatic as well as land biodiversity. The study indicated crucial biodiversity indicators for the health of the river ecosystem. By giving grades based on both the physical conditions and biodiversity of various stretches of the river plan to improve conditions is suggested.The study created guidelines for restoration and management of Mutha river ecosystem, which may be useful for rivers especially in the urban area. This paper is based on the research project "Ecological Guidelines and Recommendations for Mula-Mutha Riverfront Development" conducted by Ecological Society.

Introduction

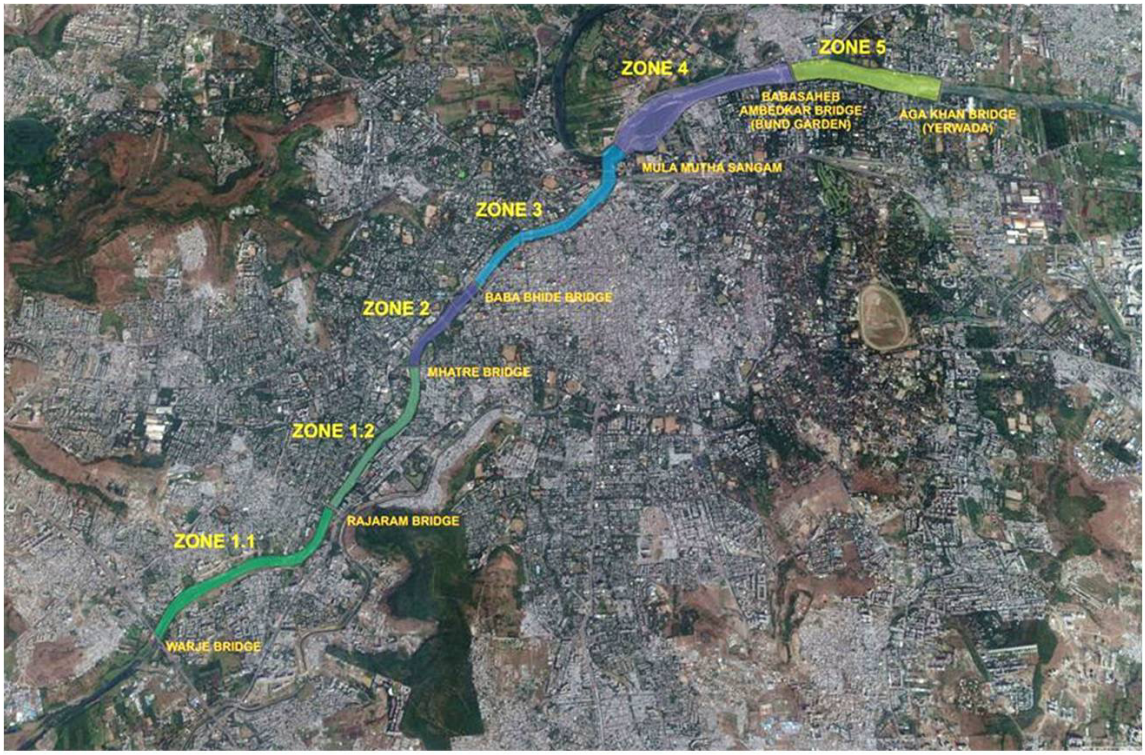
The Mula and Mutha rivers originate in Western Ghats and flow through the Municipal boundaries of Pune city. Pune city is situated along the banks of River Mutha and Mula, which are integral of Pune's culture. Citizens of Pune are intimately connected with these rivers, and have a recreational, educational and religious connection with the river and are precious assets of our city. Till few decades ago river Mutha flowing through the old part of the city was clean, and a functioning ecosystem. The city used to derive benefits of this functional ecosystem. Functional river ecosystem is linked to its physical form and the character of water flow. However now human impact on both physical and flow character has created some severe problems like

- Water flow in the channel mostly consists of sewage resulting in foul-smelling water body.
- At places there is a carpet of excessively growing, non-native water hyacinth, and creating problem of mosquitoes.

- The river flow is now not natural, completely controlled according to the necessity of water management of upstream dams. This results in redaction of flow during non-rainy season affecting biodiversity of the channel as well as banks.
- There are unwanted interventions without considering river as a natural physical system and ecosystem. River flow is channelized, making rest of the channel completely dry to harbor any biodiversity.
- The following examples of extreme change in the river system indicating disrespect to the river. The roads have been constructed in the channel itself. Besides roads channel floodplain converted into playgrounds and parking at various places. Red flood line is also not respected. Construction within red flood line is seen at some places.

Most of the problems mentioned above were realized approximately in 1970s. The intensity of those problems were much less though than the present condition. In order to resolve those problems hypothetical plan was designed based on actual river survey by Shri Prakash Gole. (Gole, 1983)

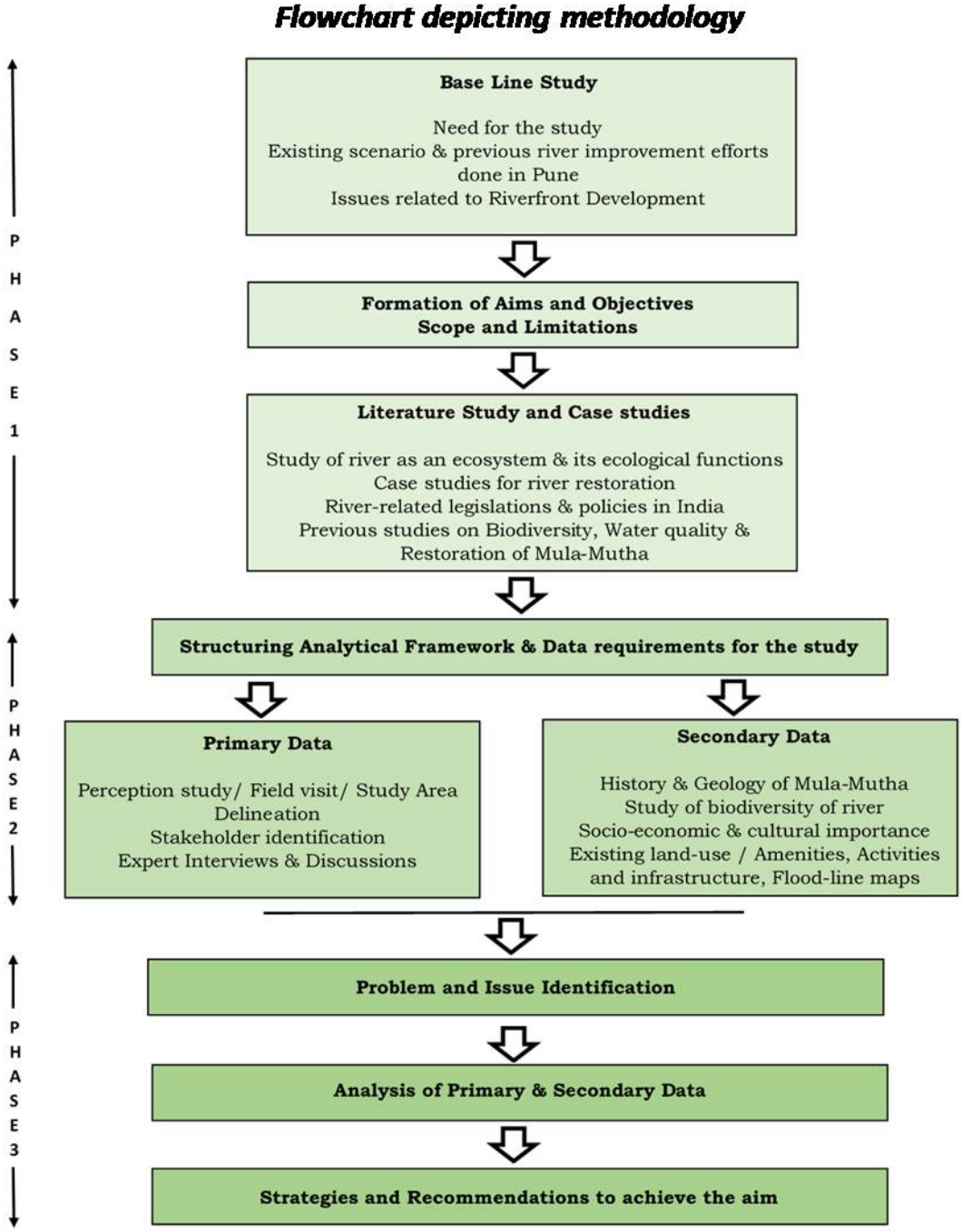
The study of all these problems in greater depth and to suggest nature- centric solutions, Ecological Society conducted a survey in the year 2018. The objective of the survey was to see present condition of the river as an ecosystem, status of cultural and religious structures, non-desirable interventions within the channel and the banks. The approach for this study is to have deeper understanding of the river ecosystem from the perspective of native biodiversity value, ecosystem services provided by the river and to search appropriate riverfront design which can satisfy citizen's requirements without compromising river's ecosystem functioning. The Pune Municipal Corporation also proposed project to develop Mutha and Mula riverfront. The design for this project on the website of PMC shows major interventions. The objective of this project is to control floods, increase in land value along the banks for commercial purpose, and creation of recreational places. This may lead to ignoring other functionalities of the river, which is not in the interest of river ecosystem itself and the public. The additional angle to Ecological Society's study was then to examine pros and cons of the PMC's "River Front Development" project. The CEE (Center for Environmental Education), the prominent organization working in environmental education in India, supported this project.



Map of the surveyed zones.

Geographical Area of the Study

The section of approximately 22 km. long stretch of river Mula-Mutha flowing through boundaries of Pune city was selected. The survey was conducted between Warje Bridge to Agakhan Bridge. (See google map No. 1 of the surveyed area.) For study purpose the river from Warje Bridge to Yerawada Bridge was divided into five zones, based on its physical and biological character. The physical character includes channel parameters, such as its cross section, width and height, substratum and habitats created by the rivers. The biotic elements survey includes aquatic vegetation, riparian vegetation study and its mapping. Observations regarding asso-



ciation between riverine habitats and aquatic vegetation and fauna were documented. Riverine avifauna is a good indicator to see the state of aquatic fauna and habitat diversity within the channel and banks. Therefore, exercise of mapping and documentation of bird species, their number and nesting sites could give us good insight of Mutha river ecosystem.

The 22 km long stretch of river Mutha was subdivided into five zones for survey purpose.

Zone 1 : This was further divided into two parts i.e.1.1 and 1.2

Zone 1.1 : Warje Bridge (on Pune-Mumbai Highway) to Rajaram Bridge

Zone 1.2 : Rajaram Bridge to Mhatre Bridge

Zone 2 : Mhatre Bridge to Baba Bhide Bridge

Zone 3 : Baba Bhide Bridge to Mula-Mutha Sangam

Zone 4 : Mula-Mutha Sangam to Ambedkar Bridge (Bund Garden)

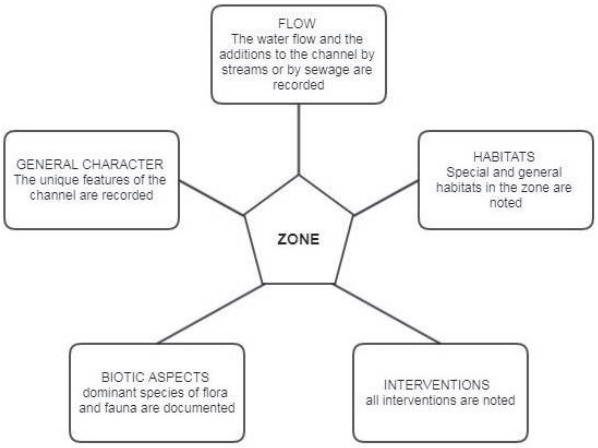


Fig. 2

Zone 5 : Babasaheb Ambedkar Bridge to Aga Khan Bridge (Yerwada)

Methodology

The methodology employed for this study is depicted in Fig. 1. The study was divided into three phases mentioned in Fig. 1.

The parameters shown in Fig. 2 were considered for the study of each zone

Based on all the above parameters all these zones were assessed for ecological health. For assessment of flora the standard literature was used such as Flora of Maharashtra state by Botanical Survey Of India and various field guides for fauna.

Out of five zones only zone 1.1 is described in this article as an example as follows :

Zone 1.1 : Warje Bridge to Rajaram Bridge

A: Physical Character

i: Channel Character

The channel in this zone is sinuous with westward bend near Vitthalwadi mandir. The cross section of the river here is asymmetric, having steeper slope on right side and gentler on the left. Large part of the channel is rocky. Potholes are a predominant habitat on the right-hand side of the channel created by erosion process. The left side of the channel is characterized by low lying sediment deposition creating marshy areas.

ii: Flow Character

The river in this part is flowing through the constructed wall causing constriction and rapid flow. This channelized mainstream receives large quantities of sewage water from the city. Downstream of the

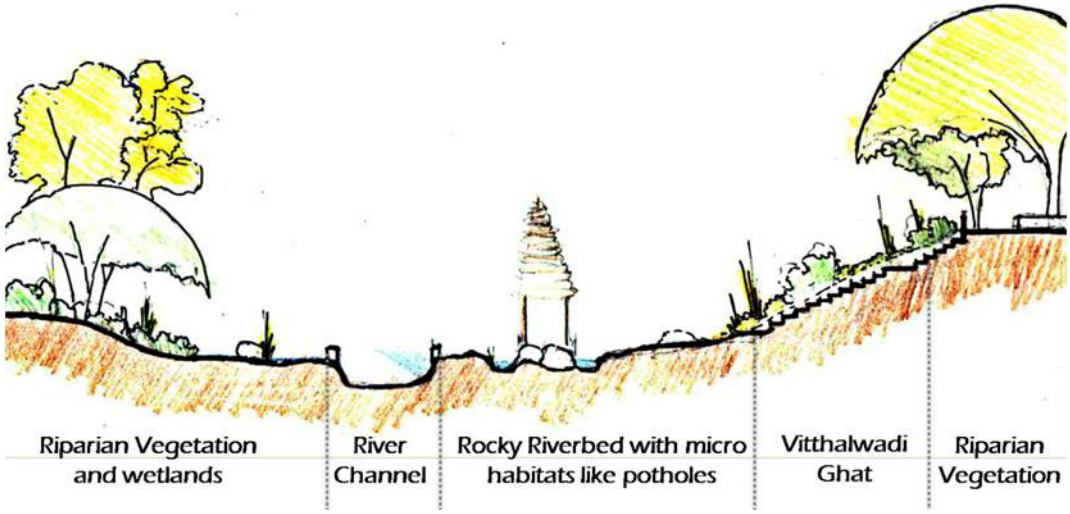


Fig. 3 : Cross Section of the River Mutha at Vitthalvadi

channelized part of the river, channel is characterized by various habitats. These habitats receive water only during monsoon floods or short seasonal pulses created by rainfall in the surrounding area. There is also a "press event" where during monsoon large quantities of water are released from the Khadakwasala dam. Many species of aquatic vegetation and fauna cannot adjust to such erratic flooding.

The Mula-Mutha river survey conducted by ecological society in 1982, "Survey of the rivers in the Pune city based on ecological factors in order to prepare an Eco-development plan to improve the river fronts of Pune" by author Prakash Gole. This report describes river flow near Vittal Mandir Zone as follows : "Once over the rocky outcrop the stream at Vithalwadi flows sluggishly (240 mtrs/hour), eddying softly over submerged rocks and lapping against small inlets in Basalt which at places are sufficiently broad to make sheltered coves and bays." This shows the riverbed used to receive natural flow till as recent as 1982.

iii. Habitats

Stretch of river between Warje and Vithalwadi hosts various types of habitats such as exposed rocks in riverbed, potholes, elongated cracks on exposed rocks, marshy areas, open grassy patches, deep pools, feeding streams, small riparian patches, meanders, riffles and pools etc. This indicates a good diversity of habitats.

B: Biotic Character

i. Flora

Corresponding to the high diversity of habitats, high floral diversity was observed in this zone. e.g. the marshy habitat supports species like Colocasia, Typha, Canna, Ludwigia, Hygrophila etc.Riparian habitats include stunted growth of Ficus racemosa, Acacia, Syzygium, Pongamiaspp. associated with nonnative and aggressive shrubs like Lantana, Eupatorium etc. In rock cracks herbaceous growth of Leucas biflora, Cleome spp. associated with few grasses were observed.Along the edges of feeding streams observed typical vegetation of Ficus racemosa, Phyllanthus reticulatus, Persicaria, Colocasia, etc. Also found pure formations of Xanthium in open patches occasionally and few open patches dominated by grass species. Invasive species water hyacinth is found in patches. Of the six zones, this zone has the maximum floral diversity.

ii. Fauna

In small riparian patches and dense shrubbery areas, birds like Prinia, Drongos, and Sunbirds, Bush chats, Indian robin were observed. Swallows were seen flying over the water surface and wagtails walking in marshy areas through Persicaria. In open patches Yellow wattle lapwings were in large numbers. Normally it is not found and therefore an important species in terms of diversity. Its roosting as well as nesting was sighted. In the channel-bed Spot bill ducks, Pond Herons, Black winged stilts were observed. White breasted kingfisher more versatile using several habitats like flowing water, riparian and channel walls. Presence of Black winged stilts and Pond heron indicates highly polluted water. Sighting of Red Munia indicate good marshy areas with Typha providing their Roosting places and open grassy patches for feeding. A rare sighting of the Cinnamon bittern indicates good marshy habitats in those areas. Wooly necked stork, Painted stork observed sometimes in open grassy patches on the banks. Numbers of scavenging birds like Crows, Black kites, were observed in large numbers because there is solid -waste dumping at many places in the channel bed and bank. Habitat diversity is good in this stretch and so the bird species show good diversity but in small number in this zone. This may be because indigenous fish diversity in the flow is almost absent. (Wagh & Ghate, 2003). According to the local fishermen near Vitthal mandir, species like "Maral" which feeds on sewage are dominant. This is a non-native, introduced species, and the growth is rampant in the sewage laden river flow.

Documentation and its mapping on Landsat imagery (Google Map 2) of flora and fauna led to identification of biodiversity hotspots in each zone. In the same image cultural entities were mapped. The example of zone 1.1 having good number of hotspots is given below.

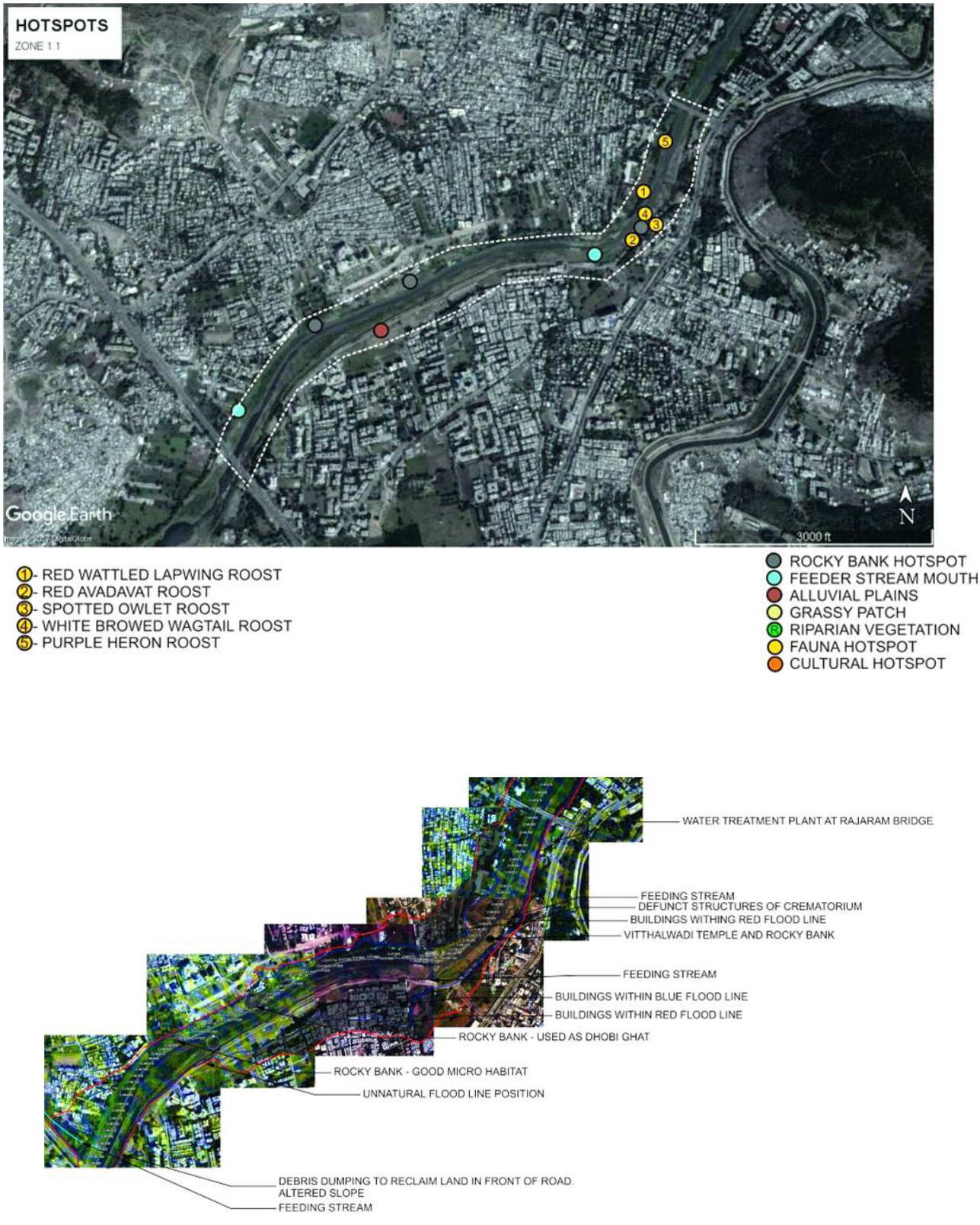
C: Biodiversity hotspots

A Biodiversity hotspot according to the Botanical Survey of India is "Hotspot is a biogeography region that is both a significant reservoir of biodiversity and is threatened with distraction." The entire zone has many important ecological features. These are critically important parts of the river ecosystem. These places are highly vulnerable and irreplaceable therefore valuable. One cannot afford to lose these features for the proper functioning of the river ecosystem. This survey also assessed which hotspots are degraded, its extent of degradation and threatened. The extent of degradation is important, so that the kind of solution can be decided. The types of hotspots considered are those which are important for river ecosystem functioning.

Biodiversity hotspots -

1.a Rocky banks

1.b Feeder stream mouths



Google Map 2 : Zone 1.1 : Warje Bridge to Rajaram Bridge

1.c Alluvial filled surfaces
1.d Grassy patches
1.e Riparian habitats
1.f Faunal hotspots

D. Cultural hotspots

Pune being historic city there are religious and cultural structures along the river. Besides temples there are Ghats and memorial structures. As all these form heritages of the Pune City, they become cultural hotspots.

E. Current status of the Zones

i Unfair use of river channel and water by citizens and administration in the following way :

- Dumping and burning of Garbage
- Dumping of construction debris
- Bank scraping
- Incorrect marking of flood lines
- Encroachments and Construction within flood lines
- Encroachments, dumping, hardscaping and narrowing of tributary feeding Streams
- Channelization of the river flow
- Defunct structures in riverbed
- Construction of roads in the channel flood plain
- Allotment of sizeable space in the channel flood-plain for parking of vehicles and play grounds.

All these unfair uses are responsible for malfunctioning of hydrological as well as ecological processes. They also indicate disregard of the beauty and sanctity of the river.

Assessment of the Surveyed Zones

The next step after the data collection and observations is to assess all these zones qualitatively. The following is the methodology to determine quality of the zones.

Qualitative Assessment of Zones

For qualitative assessment of zones, biodiversity documentation as well as channel characteristics and human interventions were considered. It facilitated ranking of these zones showing its ecological health.

Methodology

The physical and biological aspects observed of these five zones were significantly different from each other. For an effective recommendation plan, it is necessary to bring them on a common assessment platform.Therefore, use of relative rating is used. Rating of each zone was based on nine parameters and the

Table 1 : Qualitative Assessment of the Zones

Stretch-wise Quality Assessment							
	Rating	**Zone 1.1**	**Zone 1.2**	**Zone 2**	**Zone 3**	**Zone 4**	**Zone 5**
Channel	Range 0-5	3	2	0	1	4	5
Flow	Range 0-5	3	2	0	1	4	5
Habitat diversity	Range 0-5	4	2	1	0	3	5
Floral diversity	Range 0-5	4	2	1	0	5	3
Bird diversity	Range 0-5	3	2	1	0	4	5
Solid waste dumping	Yes=0, No=1	0	0	0	0	0	1
Encroachment	Yes=0, No=1	0	0	1	1	1	1
Human disturbance	Range 0-5	3	2	0	1	4	5
Roads/intervention in channel	No=1; Yes=0	0	0	0	1	1	1
Total Marks per Zone	**38**	**20**	**12**	**4**	**5**	**26**	**31**
Percent score		**52.63**	**31.58**	**10.53**	**13.16**	**68.42**	**81.58**

Table 2 : Grading of zones for ecological health

Grade 1 zones with relatively high ecological value Score > 66%	**Grade 2** zones with a relatively medium ecological value Score between 30-65%	**Grade 3** zones with the least relative ecological value Score < 33%
Zone 5 A. Strengths 1. Channel character and flow 2. Habitat diversity and bird diversity 3. Minimum solid waste dumping, encroachment, human disturbance and roads / interventions in channel. B. Opportunities 1. Floral diversity quality can be improved. C. Weakness/Threats 1. Nothing significant	**Zone 1.2** A. Strengths 1. Habitat and floral diversity B. Opportunities 1. Channel character, Flow, Bird diversity and moderate human disturbance C. Weakness/Threats 1. Solid waste dumping, encroachment and roads in river channel.	**Zone 3** A : Strengths 1. Nothing significant. B : Opportunities 1. Channel, flow, habitat diversity, floral diversity, bird diversity, moderate human disturbance C : Weakness/Threats 1. Solid waste dumping, encroachments and roads / interventions in river channel
Zone 4 A : Strengths 1. Floral diversity is the best 2. Minimum disturbance and encroachment 3. Naik island 4. Channel character, Flow, Biodiversity are strengths. B : Opportunities 1.Solid waste dumping to be stopped, protection of habitats from stresses induced due to grazing and open defecation. C. Weakness/Threats 1. Nothing significant	**Zone 1.1** A : Strengths 1. Nothing significant. B : Opportunities 1. Channel, flow, habitat diversity, floral diversity, bird diversity, moderate human disturbance C : Weakness/Threats 1. Solid waste dumping, encroachments and roads / interventions in river channel	**Zone 2** A : Strengths 1. No encroachments B : Opportunities 1. Poor biodiversity C : Weakness/Threats 1. Channel characters, flow, solid waste dumping, human disturbance and roads / intervention in channel.

existence of hotspots. The scale for rating was between the values ranging between 0 and 5. Here high marks representing the higher value.

The results shown in Table 1 are as follows : The maximum marks possible for each zone is 38. The marks were converted into percentage score. The table given below shows the assessment.

Based on the scored percentage, each zone was graded into three grades viz.1, 2 and 3. **Grade 1** zone is assigned to relatively high ecological value greater than Score > 66%. **Grade 2** zones with a relatively medium ecological value Score ranging between 30-65%. **Grade 3** zones with the least relative ecological value Score < 33%. The details of grades are shown in Table 2.

Grading of the Zones : To determine following grades, hydrological and biological strengths, opportunities and weakness of the zones were considered.

Based on the qualitative assessment and grading of the zones, broad strategy is proposed for each zone. These strategies led further to form guidelines for PMC to follow.

1 Grade 1 : Zones 4 and 5 :

Suggested Strategy : No interventions and a benign neglect

In these zones active restoration may be unnecessary as hydrological conditions are better, the channel is in natural condition with high habitat diversity. Not

significant interventions. In such a situation undisturbed recovery is suggested in this zone. These zones have a potential to recover by benign neglect but with strict protection for these zones. These zones can be designated as special zones having extremely high bird diversity associated with it. There were efforts to conserve and protect these zones by proposing sanctuary in a zone having extremely high biological value. It is necessary to take help of experts and the following steps are sufficient for the revival of this zone.

1 Conservation of aquifer discharge areas (natural springs).
2 Conservation of heritage sites such as ghats, places of worship, samadhis and memorials.
3 Conservation of all in-stream habitats like rocky patches, potholes, ponds, islands.
4 Upland zones, Riparian zones.
5 Areas deep soil profile be preserved as it has a great value of retaining climatic history through geological time. Such climatic history is in scripted in sediment deposits along the riverbank.
6 Conservation of faunal hotspots like roosting and nesting sites.
7 Restriction on human and cattle access, and provision of alternative grazing area.

2 Grade2 : Zones 1.2 and 1.1 :
Suggested Strategy : Partial intervention

Natural processes in the river corridor of these zones are relatively intact. Its potential to improve ecological conditions is high. Therefore, partial intervention is suggested. The partial intervention involves retention of existing habitat and its improvement. Unnecessary manmade interventions which are affecting river functioning are suggested to remove.

3 Grade 3 : Zones 2 and 3 :
Suggested Strategy : Substantial intervention

Zones in this grade are in a relatively poor ecological state and require substantial intervention for a managed recovery. In such a case intervention related to active restoration methods can be employed. This includes :

1 Measures for bank stability using restoration measures.
2 Improvement in the water quality of tributary stream by techniques like green bridges or biofiltration.
3 Habitat creation – within the-stream, on the banks and on the upland using restoration methods.
4 Removal of existing interventions that affect functioning of river/stream ecosystem.
5 Removal of encroachments, waste and debris dumping.
6 Creation of aquifer recharge areas with the help of hydrogeologist.
7 Creation of extensive Riparian zones by planting appropriate indigenous varieties of plants.

Vision for the rejuvenation of Mula and Mutha river ecosystem

This proposed "River Front Development "plan by PMC shows major interventions within the channel and on the banks. Such interventions disregard the river's hydrological and ecosystem values. It is therefore necessary to put forth guidelines for river front development which can be nature centric. An effort is made to incorporate ecological design in the riverfront development plan.

While suggesting ecological development for Mula and Mutha the rationale is to make river naturally flowing with its ecological functions. To overcome, both hydrological and ecological problems of river Mula-Mutha, restoration of river system appears to be best practical solution. For suggesting this one must consider that river is not an isolated single stream, but it is a part of a natural drainage system. It also has a connection with the surroundings. The extent of area adjacent to river where river processes happen is called as river corridor. The definition of river corridor is as follows: -

"River Corridor" means the land area adjacent to a river that is required to accommodate the dimensions, slope, planform, and buffer of the naturally stable channel and that is necessary for the natural maintenance or natural restoration of a dynamic equilibrium condition" ref. - it is defined in section 1422 of this title, and for minimization of fluvial erosion hazards, as delineated by the Agency of Natural Resources in accordance with river corridor protection procedures. (10 V.S.A. Chapter 32 § 752.)

In case of riverfront Development of the Mula – Mutha, it is essential to address the river along with its tributary streams. The services provided by the river are many, and it is unwise to lose these services by riverfront development project. The following is the array of services provided by the river :

They provide water supply for drinking, and other household uses, power generation and industrial uses, supply of Fish, non-extractive or in- stream benefits as flood control, transportation, birds and wildlife habitat, recreational facilities, pollution dilution, enhanced property values etc., critical ecological functions like ground water recharge, modulating stream flow etc. If

there are major changes in the flow of the river these functions are almost lost. However, those can be re-established by employing proper restoration techniques. Following image shows the role of various organisms in the functioning of river ecosystem.

Holistic view for river rejuvenation

A: Conservation of the river as a natural entity.

This necessitates that the ecological value must be prioritized over the economic utility arising from the river. The proposed interventions must respond to this natural context sensitively, and not cause any major deviations to these functions.

We recommend that utmost importance be given to the restoration of the natural design of the river, over human-centric built designs. This would not only make the project unique but also contribute to the ecological value accrued by the city.

B: Restoration of natural zones along the river

The restoration process includes rejuvenation of the structure, function and self-sustaining behavior of the river ecosystem. Following restoration strategies must be applied in stages and corresponding to the ecological status of each zone.

1. Substantial intervention for managed recovery
2. Partial intervention for assisted recovery
3. Non-intervention and undisturbed recovery

C: Maintaining environmental flow and carrying capacity

It is of prime importance to maintain the minimum requirement of environmental flow for sustenance of the river ecosystem. Mula-Mutha water flow is controlled by Khadakwasala dam. The river flow is erratic and environmental flow is many times absent causing the loss of habitats and biodiversity. It is therefore necessary to maintain environmental flow by releasing water from Khadakwasala dam.

D: Decentralized approach to river rejuvenation

Tributary streams joining Mula-Mutha contribute significant amount of water. These feeding streams are most important feature of the Mula-Mutha ecosystem. Historically, the southern tributaries like Ambil, Nagzari contributed large quantities of water to the river. Today, these tributaries are encroached upon and this has resulted into limited recharge of groundwater aquifers, reduction in the natural flow and large contribution of sewage water through these streams to the mainstream. Recent unusual floods affecting areas adjacent to these tributaries show importance of natural flow without any unfair changes in the tributary streams. Therefore, restoration of these feeding streams is also essential in the planning. And issues such as those relating to dumping of debris, solid waste, sewage and other unwarranted activities, should be urgently addressed at the catchment level.

E: Restoration for utility and aesthetic value

Restoration of the river ecosystem is important, however, to enjoy serene beauty of the river, some spaces with aesthetic value can be created along the bank without disturbing its natural ecosystem. Maintaining water quality is important for enhancing visual appeal of the riverfront. This will help the river to host macro and micro habitats for a wide array of flora and fauna. There is an immense potential for activities like bird watching, insect trails, herpetology studies along the riverbanks.

Guidelines and recommendations to re-establish river system

1. Flora and Fauna

i. While restoring the habitats care should be taken for selection of plant species and its location. Reintroduction of species of aquatic flora which are lost is essential. Refer to the list given in report "Survey of rivers in Pune city based on ecological factors to prepare an eco-development plan to improve the river fronts of the Pune" (Gole P.1983)
ii. Plantation can be done only in riparian zone and in upland area. But for selection of plant species and its location we recommend that the study of the flora of the Mutha River-Bed near Poona by V.D. Vartak (1958) and Studies on the Aquatic flowering Plants from greater Pune Area : Part I, enumeration by Vinaya Ghate and V.D.Vartak (1981) is very important. Also, recommended vegetation species for plantation in riparian and upland area in the annexure.
iii. A periodic management is necessary for complete removal of weeds.
iv. If any plantation of vegetation is to be proposed as a part of the Riverfront/Rejuvenation Project, the flora native and with respect to these respective habitats alone must be considered. Refer to Fig. 4.
v. Plantation of non-native species of flora and introduction of non-native faunal species must be strictly avoided.

2. Habitat Creation

The flow and flood rhythm of rivers create micro

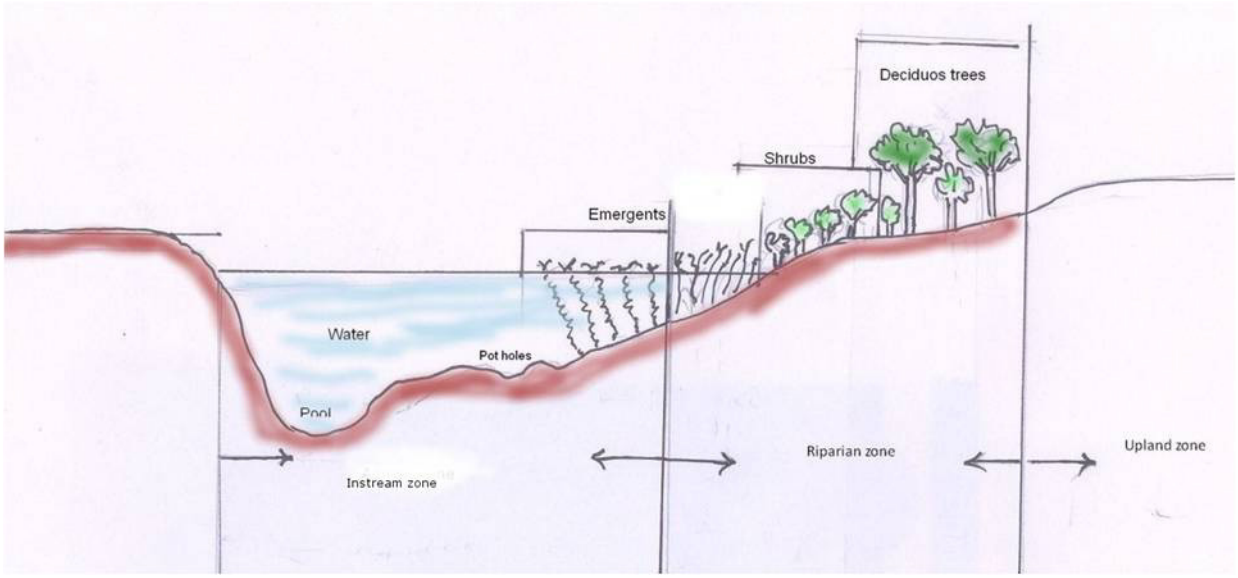


Fig. 4 : Distribution of plant types according to habitats

physical features such as, exposed rocky surfaces in the stream bed, alluvial filled surfaces on the banks, potholes, sandy surfaces on the river bed and boulder piles, etc. These riverine features are habitats for various kinds of organisms like plants, animals and microbial organisms. Oxygenation of river water takes place when it flows over exposed rocky surfaces. Several years of alluvial deposition creates riparian zones. These zones perform important functions like nutrient cycling, absorbing and releasing flood waters, maintaining fish and wildlife habitats. The riparian zone is a series of aquatic and terrestrial vegetation bands or eco tones through which matter and water exchange takes place. Similarly, habitats like grassy patches, potholes, sand flats etc. play important role in biological functions. The biotic component of the river filters contaminants in the flow. We recommend:

i. Creation of in-stream habitats such as pile of boulders in the streams, creation of sand flats, conservation of potholes and creation of riparian zone by plantation
ii. Protection of existing riparian vegetation zone.

3. Construction activities

It is important that utmost care be taken to conserve the ecosystem along with its habitats, during the construction of any interventions as a part of the Riverfront Project. During any construction of the Riverfront Project, the following guidelines can be followed.

i. The natural topography and drainage patterns of the river, riverbanks and riverbed must be conserved during construction.
ii. The natural proportion of hardscape (impervious cover) and softscape (soil, natural vegetation) must be maintained during construction. Adequate provision of recharge or discharge areas of aquifers must be kept at the time of planning of any development work.
iii. Use of natural materials such as stone, mud, mud bricks, lime, local species of timber and bamboo must be encouraged for construction activity. Use of cement should be kept to a minimum.
iv. Care must be taken that surrounding natural physical features, habitats and biodiversity is not disturbed during the construction process. Earth moving machines cause large scale destruction of habitats and are best avoided around the hotspots. Manual labor must be given priority over these machines when possible.
v. Material like mud, silt, stone and sand shall not be procured from the riverbed, banks, alluvial terraces or upland zones adjoining the river.
vi. Vehicular circulation for carrying the construction materials to the site must be planned and demarcated before commencement of the construction activity.

4. Water Quality

Presently, there is more sewage than fresh water in

the river. We suggest the following measures:

i. No untreated sewage must be added to the river. It is critical that adequate STPs, be installed for the growing population. However, just having STPs is not enough. They have to be fully functional, treated as critical infrastructure, and also up to the latest global standards, as applicable to India. They must be monitored
ii. STPs are not a long-term sustainable solution as they are unable to treat all pollutants. It is important to execute alternate sewage management systems such as bio-remediation. Another additional way to treat sewage is to reconstruct and revive in-stream habitats by restoration methods. A pilot testing is recommended before any large-scale implementation.
iii. All construction debris dumped within the red and blue flood lines to be immediately removed. This adds to the pollution and is a flood safety hazard.
iv. All encroachment within the red and blue flood lines to be demolished. This is hazardous for functioning of river ecosystem and even risk of flooding in the encroached area.
v. All the access points from which solid waste dumping happens into the river to be identified and mapped and appropriate design/planning solutions to be suggested to prevent the same.
vi. Water quality of the river must be maintained as per international/tropical standards i.e. D.O. should be 8PPM (parts per million).
vii. Non-toxic and natural alternatives to chemical domestic products such as soaps, shampoos, detergents to be identified and promoted by the Pune Municipal Corporation.

5. Channelization

The channelization restricts the free flow by confining it to channelized area of river and its feeding streams. The rest of the channel bed then remains dry and it affects adversely for aquatic flora and fauna. Therefore it is essential to remove the channelization. After removal of the channelization, following monsoon cycle should be studied to ascertain the natural character of the river before finalizing the Riverfront Development Plan.

6. Aquifers and Hydrology

The hydrology of the urban part of the Mula-Mutha River has undergone massive changes due to number of interventions in the channel and on the banks.

i. It is advised that identification and mapping of aquifers and its recharge areas is essential to enhance ground water recharge. While designing riverfront, hardscaping of the recharge areas must be avoided. These areas should be preserved and protected without any interventions. Natural vegetation on the banks should be preserved for the recharge of ground water.
ii. Natural springs in the catchment must be conserved as it adds fresh water to the river flow.
iii. Feeding streams used to flow naturally and recharging adjacent aquifers. The open space along these feeding streams which was essential for recharging of aquifers is now encroached upon by adjacent housing colonies. These feeding streams have been channelized, narrowed and concretized and look like a canal. Because of this feeding streams have lost their ecological role. So it is necessary to re-establish its natural character again.

7. Environmental flow

There is a directive by Supreme Court of India regarding environmental flow of rivers which is cited as follows :

"In NGT ruling of Pusha Saini vs. Ministry of Environment, Forest & Climate Change & Ors., about the Environmental flow of all rivers in India, the Court says *"…we direct that all the rivers in the Country shall maintain minimum 15 % to 20% of the average lean season flow of that river. However, whichever State is unable to adhere to this average percentage, in that event we grant liberty to that State Government to move the Secretary, Ministry of Environment, Forest and Climate Change (MoEFCC) who shall in consultation with the Ministry of Water Resources examine such a representation and if it is desirable to fix any lower percentage than the percentage foretasted, then it will pass appropriate order. The order should be reasoned and thereafter it would be left to the discretion of the State concerned to follow the directions of the Ministry in accordance with law. We also grant liberty to the Applicant to move MoEFCCif it has material with them in respect of any river of the country, which should have minimum environment flow in excess of 20%. If such representation is moved the same shall be disposed of by the Committee headed by Secretary in the Ministry of Environment, Forest and Climate Change in accordance with law."* (See annexture)

Based on this ruling by the NGT, we recommend that minimum E-flow of 15% to 20% of the total flow must be released in the Mula-Mutha Rivers. To decide actual quantity of e-flow, a detailed study is required.

8. Geology

i. Geologically important areas such as alluvial filled surfaces are worth preserving at least at one or two places e. g on the river bank near Mhatre Bridge. These places are important from the applied research point of view. Deposited alluvium can throw light on the paleo- climate and based on the study these sediments can aid in scientific prediction of future climate.
ii. Special geological features like spring, if identified in and along the course of the river, its preservation will be useful for conducted educational river walks and had enormous community value.

Guidelines for creating facilities for citizens and activities around the river

It is important to provide facilities and activities to fulfill citizen's daily needs. However, such facilities and activities should be allowed only at appropriate places and in a managed way.

The reason for this is an intrinsic limit to the types of facilities and their scale that a river ecosystem can sustain. Conservation of Ghats and historical monuments, gardens is also essential and its design should be complementary to nature.

1. Grazing

Presently cattle in large numbers graze along the river flow. Such large scale, round-the-year grazing is detrimental to the riverine ecosystem as well as aesthetic value of the river. It is therefore necessary to assign fixed location for grazing and animal shade.

2. Fishing

i. Fishing should be permitted only after water quality and habitats are restored.
ii. Devise a permit system to regulate fishing activity. This will prevent the over exploitation of fish.
iii. No large nets, motorboats or hi-tech equipment shall be allowed for fishing.
iv. No fishing should be allowed in the breeding periods of fish.
v. Hotspots like rocky banks and mudflats that act as spawning areas must be protected from fishing.

3. Dhobi Ghats (washing clothes on a business scale)

i. Dhobi ghats should be retained in the Riverfront development Project.
ii. Dhobi ghat facilities should be at fixed locations but away from the main stream and limited in numbers.
iii. The discharge water from such activities should be treated.
iv. Chemical detergents should not be used in washing; instead Environmental-friendly alternatives should be used.

4. Vehicle washing

Vehicle washing should be only allowed at assigned locations and with proper design.

5. Rituals

There are two rituals which are related to river water. One daily organic waste created by performing pooja is throne in the river water. Another event is of Gnapati idol immersion. For these rituals alternatives should be provided by PMC with proper publicity.

6. Eateries

Currently there are many eating places and shacks along the river. Such eateries contribute significantly to water pollution in the river. Instead, carefully planned and designed eating place facility is required. Area for eateries must be restricted. It cannot be in the physical proximity of the river. A ban should be in place and enforced on plastic bags, containers, disposable cutlery in eateries around the river.

7. Recreation

i. The river provides recreational facilities to citizens. The river is calm with a cool breeze. The beauty of the natural river is a source of joy for the citizen. To add this visual beauty, a series of gardens can be created along the rivers.
ii. Among the recreation areas around the river, some are in tune with the serene character of the river. Circus should not be allowed in the riverbed.
iii. The riverbed should not be altered for boating or any water sports.
iv. No pollutants of any kind should be released through any recreational activity.

8. Heritage

i. The Heritage structures along the river must be identified monitored, and restored.
ii. A Heritage walk connecting these structures along the river can be planned. The objective of this walk is to revive the bond between the people and the river and showcase it's history.

9. Nature trails - Birds / Insects / Flora walks

i. Restoration of the river ecosystem will boost the flora and fauna along the river. Thus, trails can be

planned for studying plants, birds, insects, fishes etc.

ii. Care must be taken to not disturb the hotspots while planning these trails.

Studies and documentation essential before execution of the riverfront development project.

It is recommended that the following studies be carried out before planning and execution of Riverfront Development / River Rejuvenation project:

i. Aquifer mapping
ii. Biodiversity assessment
iii. Habitat mapping
iv. Identifying Old growth trees, Riparian zone mapping
v. Water quality assessment
vi. Feeding Stream mapping
vii. Drainage and topography studies

Flood control and encroachments

i. In the survey it was observed that demarcated red and blue flood lines near Waraje Bridge appear to be incorrect as they are very closely spaced. In this view, it is suggested that verification of the red and blue flood lines be undertaken.
ii. It is observed during the survey that settlements and roads are within the Red and blue line. (e.g.- Location near Vithalmandir at Vithalwadi) we recommend that all encroachments within the red flood line be removed.
iii. Safety measures considering a worst-case scenario of structural damage or breakage of the three upstream dams must be considered for the same.
iv. There is an immediate need to formulate a policy to stop development on the banks of the rivers. These banks must be kept reserved for the development of riparian habitat.
v. All illegal construction and debris dumped within the red and blue flood lines must be removed.
vi. It is suggested that new retention basins should be created wherever space is available. These are useful to manage storm water runoff. It also helps in preventing over bank flooding and downstream erosion. These are commonly used in other countries and called as wet pond or wet detention basins or storm water management pond. It is an artificial lake with vegetation around the perimeter and includes a permanent pool of water in its design. These pools have wetland ecosystem value and they become complimentary to the river ecosystem.

Therefore, we recommend the creation of retention / detention basins along the river wherever sufficient space is available. An expert must be consulted for this.

Upstream and Downstream policies

i. The river is a continuum. The MuthaRiver, flowing through Pune city, has originated in the Western Ghats. What happens in the catchment area of the origin affects the river stretch in Pune city. For example, solid waste dumping in Kirkitwadi stream adds to the pollution to the river. Similarly, the happenings in Pune city will affect river corridor in the downstream area. For example, the polluted water of the city will be delivered to the downstream villages and towns. Therefore the river policy must consider the upstream and downstream effects. While formulating the policy, we recommend the Payment for Ecosystem Services (PES) Model can be adopted. This is described in detail on the UNDP website. The collection from this should be used for conservation and restoration of ecologically important areas upstream of the city, especially around the source of the Mula and Mutha rivers.
ii. Polluter pays principle may be also applied in case of bad water quality downstream. This fund may be used for water quality improvement and river restoration downstream.

Wind corridor

River provides an important service of temperature regulation. It acts as a wind corridor allowing a continuous passage of air. This passage helps in regulating temperature of the surrounding area. Considering specific case of Mutha River - "Fortunately, the Mutha River flows from west to east through the city and provides a corridor for fresh air that blows from hills to the west and south-west. Through these corridors the fresh and cool winds enter the densely populated areas much to the relief of the residents.

Tall buildings along the riverfront interfere with the free flow of fresh air. Also, broad roads while they may relieve the traffic congestion in some parts may give rise to air pollution if heavy vehicular traffic is allowed on such roads. The fumes generated by the vehicles will be blown into city's congested areas by the winds blowing from the west and further foul the atmosphere there. It is therefore, advisable to avoid heavy traffic on roads proposed to be built at the edge of the river basin and allow the winds to flow freely." (Survey of the rivers in Pune city, based on ecological factors in order to prepare an eco-development plan to improve the river-fronts of Pune, Swati Gole)

We strongly recommend that the policy level development control regulations must be framed along the riverbanks to protect this ecological function of the river.

Maintenance

i. Before the Riverfront Development project is commenced, it is of prime importance to propose a plan for its maintenance.
ii. A fund to be set up for the maintenance and upkeep of the project and the recommendations in this report.
iii. Involvement of local communities and other stakeholders must be encouraged in the maintenance of project, and conservation of hotspots.

Compensation

In case of any proposal that can potentially damage the ecosystem, its habitats, flora, fauna, aquifer recharge and discharge zones, the work shall not commence before an appropriate compensation of the ecological features or services are provided.

Recommendations for design interventions

The proposed design for riverfront development by PMC shows excess of hard scape on both channel floor and the banks. Therefore, this study suggests ecologically sound alternative designs.

1. Maintaining a balance between built interventions vs restoration / conservation

An ecologically sensitive approach to Riverfront Development of the Mula-MuthaRiver must have the right balance between the built interventions and stretches where the river has retained its natural course. It is important to have a physical connect between the city and the river. However, one must also consider that restoring the natural ecological functions and services of the river ecosystem will also contribute to and complement the built interventions. The modern view of site development is to create a design where prime focus on inclusion of natural entities, its preservation and conservation.

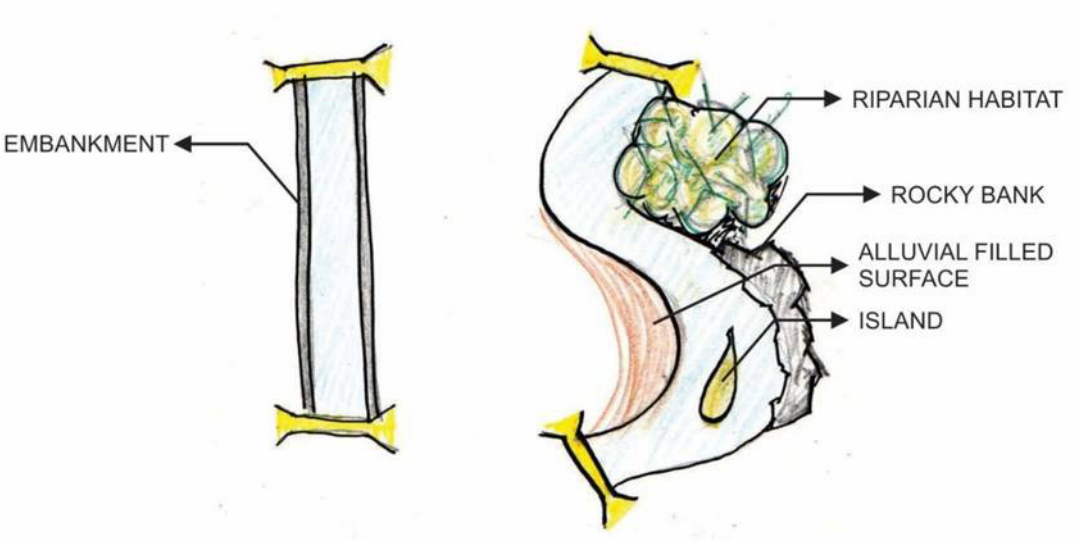
The Fig. 5 schematically illustrates the difference between the straitened river course like a canal and natural sinuous form of the river. Sinuous river course is beneficial to hydrology, especially during floods. Significant quantities flood water is contained in the channel, reducing scale of the flood. It is also beneficial to riverine organisms and aesthetically more appropriate.

2. Policy regarding access points

In the design of PMC access to river for citizens is shown all along the riverfront.To reduce stresses and managing riverfront in better manner shown in Fig. 6, it is suggested that to have limited access where control will be easy. It will also help reduce pollution and disturbance of important habitats.

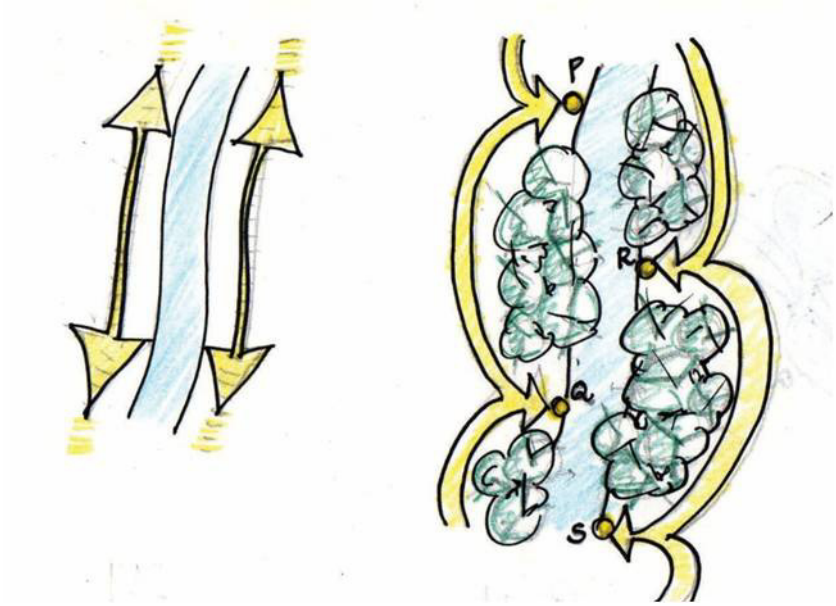
This will enhance the water quality as well as aesthetic appeal of the interventions defined as a part of the Riverfront Development Project.

We do not suggest raising barriers and depriving the citizens of the space. Barrier designs must allow a



A. proposed Chanelisation *B. suggested Natural course*

Fig. 5



A. Proposed continuous access *B. Suggested limited access*

Fig. 6

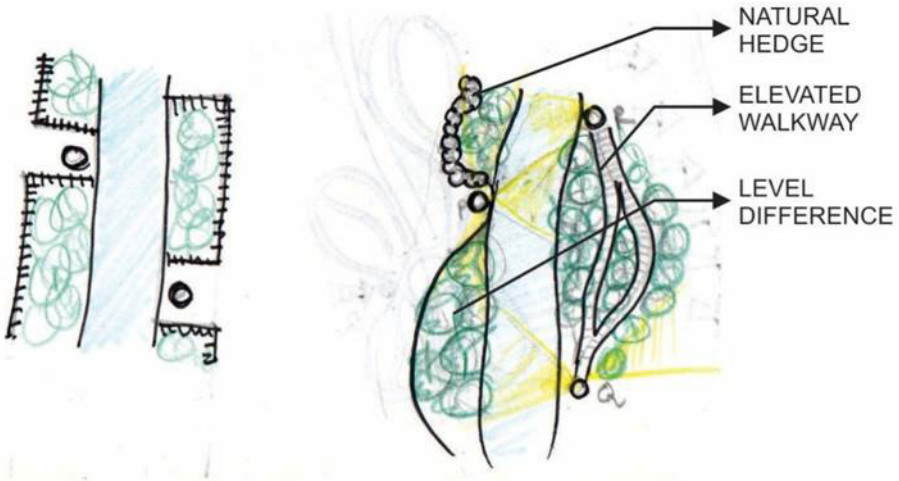
visual access to the river and its banks as shown in Fig. 7. For example, when a jogging track is to be provided for some distance, parallel to the river, it can be a raised walkway that provides a continuous view of the river but causes minimum disturbance to the habitat shown in Fig. 9.

3. Protection of natural patches by creating tall visual barriers verses access barriers ensuring visual connectivity

In the above illustration, the access restriction need not be with tall barriers as shown on the left. This can be achieved through natural hedges, level differences or raised pathways.

4. Creating stepping stones and Integrating open spaces along the river

A single huge natural space can accommodate greater biodiversity and will be more stable. However,



A Proposed barrier design *B. suggested barrier design*

Fig. 7

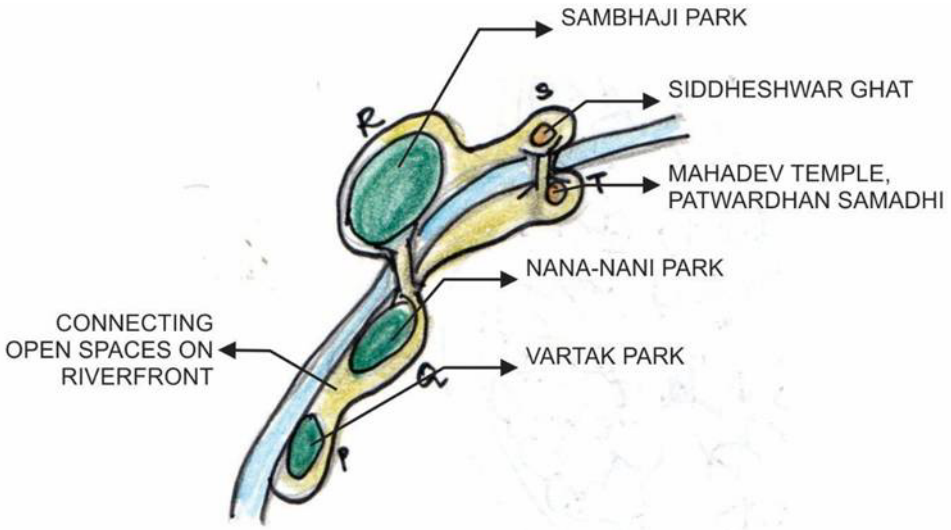


Fig. 8 : Suggested design for Integrating existing open spaces into a single riparian theme

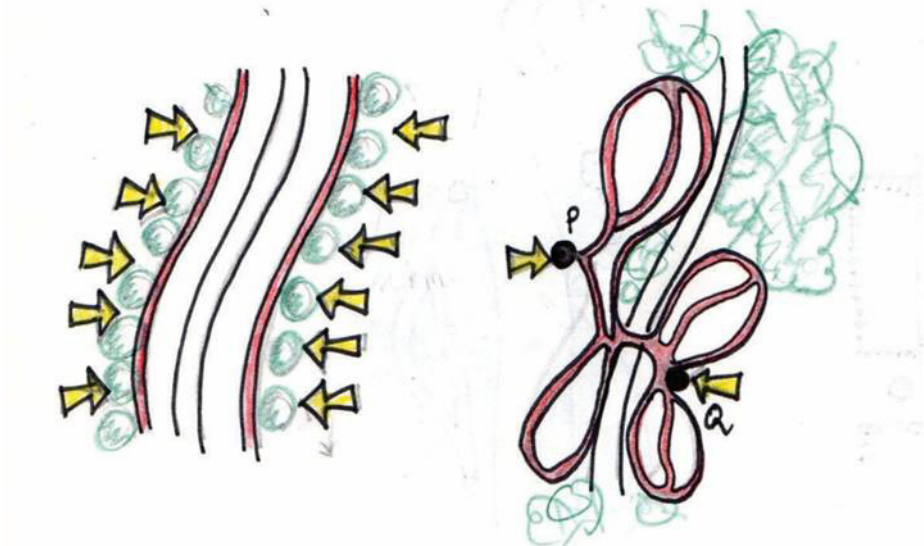
it is extremely hard to have continuous large natural areas in the cities. The small patches of wilderness can act as an island or stepping stones for organisms. Creation of such steppingstones is a known and experimented solution to strengthen urban biodiversity. Another suggestion is to create a large size natural open space for stability of the ecosystem. The good example will be of connecting several existing such small gardens along the river can be created as shown in the Fig. 9.

While connecting these open spaces to form one single open space, it is essential to develop a Riparian habitat themed garden. This way, it will also add to the ecological quality to this river stretch.

5. Effective planning of vehicular circulation

It is important to plan the circulation of vehicles, pedestrians, cyclists effectively in the riverfront design. A limited number of entry and exit points must be provided to the riverfront to minimize the habitat degradation and reduce pollution. Similarly, effective design measures must be employed to disallow solid waste dumping from bridges / causeways.

Instead of planning a linear pathway along the



A. Proposed access along the entire stretch *B. Suggested access at limited points*

Fig. 9

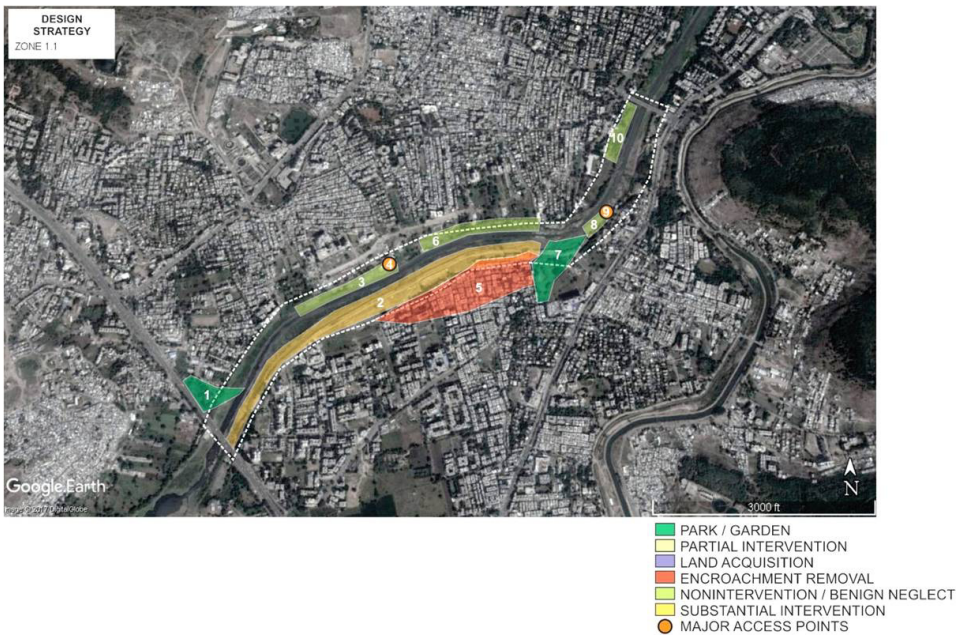
river, the same length of pathway can be designed to control entry and exit points, as shown in Fig. 9. This will reduce the pollution along the riverbanks and channel. For example, figure A, shows continuous access and figure B shows controlled points. Car parking can be planned only at such limited entry / exit points.

Specific recommendations for each zone

The biodiversity survey outcome of each zone was mapped and the interventions praposed by PMC were considered to suggest interventions and specific management plan for each zone.Below is the example of zone 1.1 and 1.2

For zone No. 1.1 a partial Intervention strategy is recommended. The various patches in this zone need specific management.

1. Patch 1 This is the mouth of a feeder stream that meets the river on the left bank. The slope to the left is a gradual one, and there is a lot of area available around the mouth of this nala. Moreover, the flow velocity of the stream being slow, developing a Nala park (Osho park, in Koregaon Park) in this area will be the most effective design strategy.
2. Patch 2 This is the stretch wherein a road was constructed illegally. After the NGT verdict, the work of removing the construction material that was dumped for the road is currently in progress. However, due to the constant movement of heavy earth moving vehicles in this patch, the natural ecosystem is damaged to a large extent. Thus, substantial intervention in terms of habitat creation, plantation and maintenance is required here. Naturally, alluvial field deposits may have been located here. Thus, efforts must be made to restore this type of ecosystem here.
3. Patch 3 and Patch 6 These patches comprise largely of rocky banks. However, the water no longer reaches these rocks due to the concrete channels constructed in the river bed. These channels must be removed, and the changes must be observed for one seasonal cycle. Accordingly, assisted recovery of habitats in this rocky patch must be attempted.
4. Point 4 This is an access point, used as a dhobi ghat. While water from the river is not actually used for washing clothes, it was observed that the wastewater from washing goes directly into the river. Also, the rocks are used to dry clothes. It is important to retain this activity, as it shows a connect of the people to the river, in their daily routine. However, the activity must be restructured so that the river pollution is prevented. Natural detergents such as Ritha must be encouraged and ones having chemical pollutants must be banned at this spot. Also, the wastewater may be passed through root zone filter beds before



Google Map 3 : A. Zone 1.1

being let out into the river.

5. Patch 5 One can see numerous structures built within the red and blue flood lines here. It is important for the sake of safety, river ecology as well as law enforcement that these be removed urgently.
6. Patch 7 This is the mouth of a nala that joins the right bank of the river, before Vitthalwadi. It emerges from a settlement nearby and passes under a bridge before joining the river. The area between the nala and the settlement is already cordoned off. Thus, it will be easy to develop like a Nala Park here that will be responsible for a decentralized treatment of the water entering the river. It will also act as a usable open space / garden area for the settlement.
7. Patch 8 This is a rocky patch adjoining the Mahadev temple at Vitthalwadi. It contains nascent stages of potholes. Also, once the channels are demolished, the rocky habitats should be observed, developed and conserved.
8. Point 9 Access point 9 is the Mahadev temple at Vitthalwadi. It experiences peak rush during Ekadashi and Ganpati visarjan. It is essential to control the stress on the rocky habitats nearby during these festivals. Also, circulation must be planned such that there is no disturbance to the hotspots nearby.
9. Patch 10 This is a patch in front of the crematorium in Vitthalwadi. Once the access is restricted, it will be an ideal location for developing Riparian vegetation.

In case of zone No. 1.2 strategy can be as follows :

1. Patches 1, 2 and 5 these patches include grassy as well as marshy vegetation. However, one can observe stresses due to illegal dumping of solid waste and debris from the wedding lawns located in the upland zone.
2. Patch 3 This is a marshy patch that is a good habitat for birds, due to absence of channelization. This patch must be protected in its natural state.
3. Patch 4 This is the mouth of a nala, which is actually the discharge from the Parvati water treatment plant. One can observe that a sizeable amount of water is carried into the river, with great velocity here. The nala and the area around it is cordoned off with a fence. It is ideal to make a stroll garden themed Nala Park.
4. Point 6 This is the Dattawadivisarjan Ghat. Clothes and utensil washing activity takes place

Google Map 4 : B. Zone 1.2

here in the morning. It can be treated the same way like Point 4 in Zone 1.1. Access must be limited to the ghat itself, and people as well as cattle must not be allowed to roam from the ghat to the adjacent patches 5 and 3.

General recommendations on what to avoid

1. No channelization of the river. This is a well-studied aspect of river ecosystems and there are ample references which support the free flow of river in its own channel. This is clearly the most important DON'T for Mula-Mutha.
2. No concrete / tar / paver block or roads on any of the river banks, streams, riparian zones and springs. They must be retained in their natural state. This retains the character of the river and makes it look like a river and not a canal.
3. No high-rise buildings on the banks. This is to allow an unrestricted view of the river. Within a bustling city, a natural river has the potential to be a place of natural beauty. This must be preserved at all times. As there are hardly any open spaces left for Pune citizen, this is a good opportunity.
4. No eateries/ restaurants / take-aways on the banks and in the river bed. We have identified these as a significant source of pollution and intervention to the natural processes on the banks. Moreover, the eateries today are in the zone where riparian vegetation is possible to be nurtured.
5. Do not use excessive lighting in the river bed. No flood lights or any other forms of excessively bright lights. This is detrimental to insects and nocturnal fauna. We recommend a separate study of lighting for the river zone.
6. No construction / structure in any of the identified ecologically important hotspots. This is critical to the restoration of flora and fauna in the river ecosystem. We have identified many stretches where riverfront development structures can be made.
7. Do not use any non-native species of vegetation for any kind of plantation in the river bed and on its banks. All plantations must only be of native species, relevant to this region of the country and habitat. We have provided a list of such vegetation.
8. Do not allow any untreated water or sewage to enter the river. This is critically important when we are trying to revive aquatic life.
9. Do not allow activities like large gatherings, weddings, circus, exhibitions, political rallies, Dandiya, etc. in the river bed (Refer to the NGT ruling in the case of Art of Living World Culture festival case).

Conclusion

The city of Pune is blessed with two rivers flowing within it and their confluence. In this age where cities are turning similar with undifferentiated architectural structures, it is critical to preserve a naturally endowed character of the city. A well-maintained river is not just a source of charm for its citizen, but also a provider of vital environmental services that every city needs for healthy functioning. It is this aspect of the river that we strongly recommend being conserved and nurtured, in the riverfront development project. Our recommendations are prioritized on ecological and cultural aspects and employ a holistic perspective of looking at the river as a continuum and a living ecosystem. We are aware that this report has limitations, but we hope that the project designers and planners will find the guidelines worthy of consideration. We would be glad to initiate further discussions to the stakeholders.

"Design needs to shift from a paradigm of transforming nature to one of transforming society; by improving the quality of life and relationships between all living things and the built environment" Prakash Gole, Understanding Reality.

Full Check-list of Flora of Mula-Mutha

Plant Checklist OF Mula-Mutha River

Trees				
No.	**Scientific Names**	**Common Name**	**Family**	**Occurrence**
1	*Acacia auriculiformis Benth.*	Australian Babhul	Leguminosae	Occasional
2	*Acacia chundra (Rottler) Willd.*	Khair	Leguminosae	Occasional
3	*Acacia nilotica (L.) Delile*	Babhul	Leguminosae	Common
4	*Acacia polyacantha Willd.*	Pandhra Khair	Leguminosae	Occasional
5	*Adansonia digitata L.*	Baobab	Malvaceae	Occasional
6	*Aegle marmelos (L.) Corrêa*	Bel	Rutaceae	Occasional
7	*Ailanthus excelsa Roxb.*	Maharukh	Simaroubaceae	Rare
8	*Albizia lebbeck (L.) Benth.*	Shirish	Leguminosae	Occasional
9	*Albizia saman (Jacq.) Merr.*	Rain tree	Leguminosae	Occasional
10	*Alstonia scholaris (L.) R.Br.*	Satvin	Apocynaceae	Common
11	*Annona squamosa L*	Sitaphal	Annonaceae	Occasional
12	*Azadirachta indica A.Juss.*	Kadunimb	Meliaceae	Occasional
13	*Bauhinia purpurea L.*	Kanchan	Leguminosae	Occasional
14	*Bombax ceiba L.*	Katesawar	Malvaceae	Occasional
15	*Broussonetia papyrifera (L.) Vent*	Paper Mulberry	Moraceae	Common
16	*Capparris grandis L.f.*	Pachunda	Capparaceae	Occasional
17	*Carica papaya L.*	Papai	Caricaceae	Occasional
18	*Cocos nucifera L.*	Naral	Arecaceae	Occasional
19	*Cordia dichotoma G.Forst.*	Bhokar	Boraginaceae	Occasional
20	*Couroupita guianensis Aubl.*	Kailaspati	Lecythidaceae	Occasional
21	*Dalbergia sissoo DC.*	Shisav	Leguminosae	Common
22	*Delonix regia (Hook.) Raf.*	Gulmohor	Leguminosae	Occasional
23	*Eucalyptus globulus Labill.*	Nilgiri	Myrtaceae	Common
24	*Ficus benghalensis L.*	Wad	Moraceae	Occasional
25	*Ficus hispida L. f.*	Dhedumbar	Moraceae	Occasional
26	*Ficus racemosa L.*	Umbar	Moraceae	Occasional
27	*Ficus religiosa L.*	Pimpal	Moraceae	Occasional
28	*Gliricidia sepium (Jacq.) Walp.*	Undirmari	Leguminosae	Common
29	*Gmelina arborea Roxb.*	Shivan	Lamiaceae	Occasional
30	*Grewia tiliifolia Vahl*	Dhaman	Malvaceae	Occasional

No.	Scientific Names	Common Name	Family	Occurrence
31	*Holoptelea integrifolia Planch.*	Waval	Ulmaceae	Occasional
32	*Leucaena leucocephala (Lam.) de Wit*	Subabhul	Leguminosae	Common
33	*Limonia acidissima Groff*	Kavath	Rutaceae	Occasional
34	*Mangifera indica L*	Amba	Anacardiaceae	Occasional
35	*Millingtonia hortensis L.fil.*	Booch	Bignoniaceae	Common
36	*Mimusops elengi L.*	Bakul	Sapotaceae	Occasional
37	*Morinda pubescens Sm.*	Bartondi	Rubiaceae	Occasional
38	*Moringa oleifera Lam.*	Shewaga	Moringaceae	Occasional
39	*Muntingia calabura L.*	Singapore cherry	Muntingiaceae	Occasional
40	*Neolamarckia cadamba (Roxb.) Bosser*	Kadamb	Rubiaceae	Occasional
41	*Peltoforum pterocarpum Auct. non K.Heyne*	Tambadsheng	Leguminosae	Common
42	*Phoenix sylvestris (L.) Roxb.*	Shindi	Arecaceae	Occasional
43	*Pithecellobium dulce (Roxb.)Benth.*	Vilayati Chinch	Leguminosae	Common
44	*Polyalthia longifolia (Sonn.) Thwaites*	Ashok	Annonaceae	Common
45	*Pongamia pinnata (L.) Pierre*	Karanj	Leguminosae	Occasional
46	*Prosopis juliflora (Sw.) DC*	Wedi babhul	Leguminosae	Common
47	*Psidium guajava L.*	Peru	Myrtaceae	Occasional
48	*Pterospermum acerifolium (L.) Willd.*	Muchkund	Malvaceae	Occasional
49	*Putranjiva roxburghii Wall.*	Putranjiva	Putranjivaceae	Occasional
50	*Salix tetrasperma Roxb.*	Walunj	Salicaceae	Rare
51	*Santalum album L.*	Chandan	Santalaceae	Occasional
52	*Senna siamea (Lam.) H.S.Irwin& Barneby*	Kashid	Leguminosae	Occasional
53	*Solanum nigrum L.*		Solanaceae	Occasional
54	*Spathodea campanulata Beauv*	Pichkari	Bignoniaceae	Common
55	*Spathodea campanulata P.Beauv.*	Pichkari	Bignoniaceae	Occasional
56	*Sterculia foetida L.*	Punai	Malvaceae	Occasional
57	*Syzygium cumini (L.) Skeels*	Jambhul	Myrtaceae	Occasional
58	*Syzygium heyneanum (Duthie)Wall.ex Gamble*	Panjambhul	Myrtaceae	Rare
59	*Tamarindus indica L.*	Chinch	Leguminosae	Occasional
60	*Terminalia arjuna (Roxb. ex DC.) Wight & Arn.*	Arjun	Combretaceae	Occasional
61	*Terminalia catappa L.*	Badam	Combretaceae	Occasional
62	*Terminalia cuneata Roth*	Arjun	Combretaceae	Occasional
63	*Trema orientalis (L.) Blume*	Ghol	Cannabaceae	Occasional

No.	Scientific Names	Common Name	Family	Occurrence
64	*Zizipus mauritiana Lamk.*	Bor	Rhamnaceae	Occasional
Herbs				
1	*Abutilon indicum (L.) Sweet*	Mudra	Malvaceae	Common
2	*Acalypha ciliata Forssk.*		Euphorbiaceae	Common
3	*Achyranthes aspera L.*	Aaghada	Amaranthaceae	Common
4	*Aeschynomene indica L.*		Leguminosae	Common
5	*Ageratum conyzoides (L.) L.*		Compositae	Common
6	*Alternanthera philoxeroides (Mart.) Griseb.*	Alligator weed	Amaranthaceae	Abundant
7	*Alternanthera pungens Kunth*		Amaranthaceae	Occasional
8	*Alternanthera sessilis (L.) R.Br. ex DC.*	Chabuk kata	Amaranthaceae	Abundant
9	*Alysicarpus tetragonolobus Edgew.*		Leguminosae	Occasional
10	*Amaranthus spinosus L.*	Katemath	Amaranthaceae	Common
11	*Amaranthus viridis L.*	Math	Amaranthaceae	Common
12	*Ammannia baccifera L.*		Lythraceae	Rare
13	*Apluda mutica L.*		Poaceae	Common
14	*Argemone mexicana L.*	Pivala dhotra	Papaveraceae	Common
15	*Asclepias curassavica L.*	Haladi Kunku	Apocynaceae	Common
16	*Azolla pinnata R. Br.*		Salviniaceae	Abundant
17	*Bacopa monnieri (L.) Wettst.*	Neerbrahmi	Plantaginaceae	Occasional
18	*Bambusa vulgaris Schrad.*	Yellow Bamboo	Poaceae	Occasional
19	*Bidens biternata (Lour.) Merr. & Sherff*		Compositae	Occasional
20	*Boerhavia diffusa L.*	Punarnava	Nyctaginaceae	Occasional
21	*Brassica juncea (L.) Czern.*	Mohori	Brassicaceae	Occasional
22	*Canna indica L.*	Kardal	Cannaceae	Occasional
23	*Canscora diffusa (Vahl) R.Br. ex Roem. & Schult.*	Kilwar	Gentianaceae	Occasional
24	*Celosia argentea L.*	Kurdu	Amaranthaceae	Common
25	*Centella asiatica (L.) Urb.*	Mandukparni	Apiaceae	Occasional
26	*Chloris virgata Sw.*		Poaceae	Common
27	*Chromolaena odorata (L.) R.M.King& H.Rob.*	Ranmari	Compositae	Abundant
28	*Cleome rutidosperma DC.*		Cleomaceae	Rare
29	*Cleome viscosa L.*	Pivali Tilwan	Cleomaceae	Occasional
30	*Colocassia esculenta (L.) Scott*	Ran-alu	Araceae	Common
31	*Commelina benghalensis L.*	Keni	Commelinaceae	Common

No.	Scientific Names	Common Name	Family	Occurrence
32	*Commelina caroliniana Walter*		Commelinaceae	Common
33	*Corchorus sp.*	Chunch	Malvaceae	Common
34	*Cosmos sulphureus Cav.*	Cosmos	Compositae	Common
35	*Croton bonplandianus Baill.*		Euphorbiaceae	Occasional
36	*Cullen corylifolium (L.) Medik.*	Bavachi	Leguminosae	Common
37	*Cyanotis fasciculata (B.Heyne ex Roth) Schult. & Schult.f.*	Nilwanti	Commelinaceae	Common
38	*Cyanthillium cinereum (L.) H.Rob.*	Sahdevi	Compositae	Common
39	*Cynodon dactylon (L.) Pers.*	Harali	Poaceae	Common
40	*Cyperus scariosus R.Br.*	Lavhale	Cyperaceae	Occasional
41	*Dactyloctenium aegyptium (L.) Willd.*		Poaceae	Common
42	*Datura innoxia Mill.*	Dhotara	Solanaceae	Occasional
43	*Datura metel L.*	Dhotara	Solanaceae	Rare
44	*Desmodium tortuosum (Sw.) DC.*		Leguminosae	Common
45	*Digitaria ciliaris (Retz.) Koeler*		Poaceae	Common
46	*Dinebra retroflexa (Vahl) Panz.*		Poaceae	Common
47	*Echinochloa colona (L.) Link*		Poaceae	Common
48	*Eclipta prostrata (L.) L.*	Maka	Compositae	Occasional
49	*Eichhornia crassipes (Mart.) Solms*	Jalparni	Pontederiaceae	Abundant
50	*Emilia sonchifolia (L.) DC. ex DC.*		Compositae	Occasional
51	*Euphorbia heterophylla L.*	Dudhi	Euphorbiaceae	Common
52	*Euphorbia hypericifolia L.*	Dudhi	Euphorbiaceae	Common
53	*Exacum pedunculatum L.*		Gentianaceae	Occasional
54	*Glinus lotoides L.*		Molluginaceae	Common
55	*Gomphrena sp.*		Amaranthaceae	Occasional
56	*Grangea maderaspatana (L.) Poir.*	Mashpatri	Asteraceae	Common
57	*Gynandropsis pentaphylla (L.)*		Capparaceae	Common
58	*Heliotropium indicum L.*	Bhurundi	Boraginaceae	Occasional
59	*Hibiscus sp.*		Malvaceae	Occasional
60	*Hygrophila auriculata (Schumach.) Heine*	Talimkhana	Acanthaceae	Abundant
61	*Hyptis suaveolens (L.) Poit.*	Darptulas	Lamiaceae	Occasional
62	*Indigofera glandulosa Wendl.*	Borpudi	Leguminosae	Rare
63	*Ipomoea aquatica Forssk.*	Nalichi Bhaji	Convolvulaceae	Abundant
64	*Lagascea mollis Cav.*		Compositae	Occasional

No.	Scientific Names	Common Name	Family	Occurrence
65	*Launaea procumbens (Roxb.) Ramayya & Rajagopal*		Compositae	Occasional
66	*Lemna gibba L.*		Araceae	Abundant
67	*Leonotis nepetifolia (L.) R.Br.*	Deepmal	Lamiaceae	Occasional
68	*Leucas biflora (Vahl) Sm.*		Lamiaceae	Rare
69	*Leucas longifolia Benth.*		Lamiaceae	Common
70	*Ludwigia octovalvis (Jacq.) P.H.Raven*	Panlawang	Onagraceae	Common
71	*Martynia annua L.*	Vinchawi	Martyniaceae	Occasional
72	*Mollugo pentaphylla L.*		Molluginaceae	Common
73	*Ocimum gratissimum L.*	Tulas	Lamiaceae	Occasional
74	*Oldenlandia corymbosa L.*		Rubiaceae	Common
75	*Oxalis corniculata L.*	Amboshi	Oxalidaceae	Common
76	*Parthenium hysterophorus L.*	Gajar Gavat	Compositae	Abundant
77	*Persicaria glabra (Willd.) M.Gómez*	Sheral	Polygonaceae	Abundant
78	*Phyla nodiflora (L.) Greene*	Neerbrahmi	Verbenaceae	Occasional
79	*Phyllanthus niruri L.*	Bhuiawali	Phyllanthaceae	Common
80	*Physalis minima L.*	Popati	Solanaceae	Abundant
81	*Pistia stratiotes L.*		Araceae	Occasional
82	*Plumbago zeylanica L.*	Chitrak	Plumbaginaceae	Occasional
83	*Portulaca oleracea L.*	Gholu	Portulacaceae	Common
84	*Ruelia tuberosa L*		Acanthaceae	Occasional
85	*Senna sophera (L.) Roxb.*		Leguminosae	Occasional
86	*Senna tora (L.) Roxb.*	Takala	Leguminosae	Abundant
87	*Senna uniflora (Mill.) H.S.Irwin& Barneby*		Leguminosae	Abundant
88	*Sesamum orientale L.*	Rantil	Pedaliaceae	Occasional
89	*Setaria pumila (Poir.) Roem. & Schult.*		Poaceae	Common
90	*Sida acuta Burm.f.*	Bala	Malvaceae	Occasional
91	*Solanum lycopersicum L.*	Tomato	Solanaceae	Occasional
92	*Solanum virginianum L.*	Katerigani	Solanaceae	Occasional
93	*Spermacoce pusilla Wall.*		Rubiaceae	Common
94	*Spilanthes acmella (L.) L.*		Compositae	Occasional
95	*Spirodela polyrrhiza (L.) Schleid.*	Tikali	Araceae	Abundant
96	*Synedrella nodiflora (L.) Gaertn.*		Compositae	Abundant
97	*Themeda quadrivalvis (L.) Kuntze*		Poaceae	Common

No.	Scientific Names	Common Name	Family	Occurrence
98	*Tithonia rotundifolia (Mill.) S.F.Blake*		Compositae	Common
99	*Trianthema portulacastrum L.*		Aizoaceae	Occasional
100	*Tridax procumbens (L.) L.*	Ekdandi	Compositae	Common
101	*Triumfetta rhomboidea Jacq.*		Malvaceae	Common
102	*Typha angustifolia L.*	Ramban/Pankanis	Typhaceae	Common
103	*Urena lobata L.*		Malvaceae	Occasional
104	*Verbascum chinense (L.) Santapau*	Kutaki	Scrophulariaceae	Occasional
105	*Wedelia triloba (L.) Hitchc.*	Wedelia	Compositae	Occasional
106	*Withania somnifera (L.) Dunal.*	Ashwagndha	Solanaceae	Common
107	*Xanthium strumarium L.*	Shankeshwar	Compositae	Common
Shrubs				
1	*Calotropis gigantea (L.) Dryand.*	Rui	Apocynaceae	Occasional
2	*Chrozophora rottleri (Geiseler) A.Juss. ex Spreng.*	Suryvarti	Euphorbiaceae	Common
3	*Dalbergia melanoxylon Guill. & Perr.*	Patangi	Leguminosae	Common
4	*Grewia hirsuta Vahl*		Malvaceae	Rare
5	*Homonoia riparia Lour.*	Sherani	Euphorbiaceae	Occasional
6	*Ipomoea carnea Jacq.*	Besharam	Convolvulaceae	Common
7	*Lantana camara L.*	Tantani	Verbanaceae	Common
8	*Phyllanthus reticulatus Poir.*	Panjuli	Phyllanthaceae	Common
9	*Pluchea ovalis (Pers.) DC.*		Compositae	Occasional
10	*Pseudarthria viscida (L.) Wight & Arn.*		Leguminosae	Common
11	*Ricinus communis L.*	Erand	Euphorbiaceae	Common
12	*Sesbania sesban (L.) Merr.*	Shevari	Leguminosae	Common
13	*Solanum torvum Sw.*	Kutri	Solanaceae	Occasional
14	*Vitex negundo L.*	Nirgudi	Lamiaceae	Occasional
15	*Woodfordia fruticosa (L.) Kurz*	Dhayati	Lythraceae	Occasional
Climbers				
1	*Argyreia nervosa (Burm. f.) Bojer*	Samusrashok	Convolvulaceae	Occasional
2	*Capparis zeylanica L.*	Govindi	Capparaceae	Occasional
3	*Cardiospermum halicacabum L.*		Sapindaceae	Occasional
4	*Celastrus paniculatus Willd.*	Malkangoni	Celastraceae	Occasional
5	*Coccinea grandis (L.)Voigt*	Tondali	Cucurbitaceae	Common
6	*Cocculus hirsutus (L.) W.Theob.*	Vasanwel	Menispermaceae	Common

No.	Scientific Names	Common Name	Family	Occurrence
7	*Combretum ovalifolium Roxb.*	Piluki	Combretaceae	Occasional
8	*Cryptolepis dubia (Burm.f.) M.R.Almeida*	Kavali	Apocynaceae	Occasional
9	*Cryptostegia grandiflora Roxb. ex R.Br.*		Apocynaceae	Occasional
10	*Diplocyclos palmatus (L.) Jeffrey.*	Shivlingi	Cucurbitaceae	Occasional
11	*Ipomoea cairica (L.) Sweet*	Railway creeper.Garwel	Convolvulaceae	Common
12	*Ipomoea nil (L.) Roth*		Convolvulaceae	Occasional
13	*Ipomoea obscura (L.) Ker Gawl.*		Convolvulaceae	Occasional
14	*Ipomoea triloba L.*		Convolvulaceae	Common
15	*Macroptilium atropurpureum (DC.) Urb.*		Leguminosae	Occasional
16	*Mukia maderaspatana (L.)M.Roem.*	Chirati	Cucurbitaceae	Occasional
17	*Passiflora foetida L*	Welghani	Passifloraceae	Common
18	*Pergularia daemia (Forsskal) Chiov.*	Utran	Apocynaceae	Occasional
19	*Teramnus labialis (L.f.) Spreng.*		Leguminosae	Occasional
20	*Tinospora cordifolia(willd.)Miers.*	Gulwel	Menispermaceae	Common
21	*Vigna radiata (L.) R.Wilczek*	Moong	Leguminosae	Occasional
22	*Ziziphus oenopolia (L.) Mill.*		Rhamnaceae	Occasional

Annexure 2 : Zonewise Checklist of Flora

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
1	*Abutilon indicum* (L.) Sweet	✓		✓	✓	✓	✓
2	*Acacia auriculiformis* Benth.	✓	✓	✓		✓	✓
3	*Acacia chundra* (Rottler) Willd.					✓	✓
4	*Acacia nilotica* (L.) Delile	✓	✓	✓	✓	✓	✓
5	*Acacia polyacantha* Willd.	✓		✓			✓
6	*Acalypha ciliata* Forssk.	✓	✓	✓	✓	✓	✓
7	*Achyranthes aspera* L.	✓	✓	✓	✓	✓	✓
8	*Adansonia digitata* L.						✓
9	*Aegle marmelos* (L.) Corrêa						✓
10	*Aeschynomene indica* L.	✓	✓	✓		✓	✓
11	*Ageratum conyzoides* (L.) L.	✓	✓	✓	✓	✓	✓
12	*Albizia lebbeck* (L.) Benth.	✓		✓		✓	✓
13	*Ailanthus excelsa* Roxb.					✓	
14	*Albizia saman* (Jacq.) Merr.	✓	✓	✓	✓	✓	✓
15	*Alstonia scholaris* (L.) R.Br.		✓	✓		✓	✓
16	*Alternanthera philoxeroides* (Mart.) Griseb.	✓	✓	✓	✓	✓	✓
17	*Alternanthera pungens* Kunth		✓				✓
18	*Alternanthera sessilis* (L.) R.Br. ex DC.	✓	✓	✓	✓	✓	✓
19	*Alysicarpus tetragonolobus* Edgew.	✓		✓		✓	✓
20	*Amaranthus spinosus* L.	✓	✓	✓	✓	✓	✓
21	*Amaranthus viridis* L.	✓	✓	✓	✓	✓	✓
22	*Ammannia baccifera* L.	✓				✓	
23	*Annona squamosa* L	✓	✓				✓
24	*Apluda mutica* L.	✓				✓	✓
25	*Argemone mexicana* L.	✓	✓	✓	✓	✓	✓
26	*Argyreia nervosa* (Burm. f.) Bojer	✓				✓	✓
27	*Asclepias curassavica* L.	✓	✓	✓	✓	✓	✓
28	*Azadirachta indica* A.Juss.	✓	✓	✓	✓	✓	✓
29	*Azolla pinnata* R. Br.	✓	✓			✓	✓
30	*Bacopa monnieri* (L.) Wettst.	✓					✓
31	*Bambusa vulgaris* Schrad.	✓		✓			
32	*Bauhinia purpurea* L.	✓			✓	✓	
33	*Bidens biternata* (Lour.) Merr. & Sherff	✓	✓	✓		✓	✓
34	*Boerhavia diffusa* L.	✓		✓		✓	✓
35	*Bombax ceiba* L.	✓		✓		✓	✓
36	*Brassica juncea* (L.) Czern.	✓	✓	✓	✓	✓	
37	*Broussonetia papyrifera* (L.) Vent	✓	✓			✓	
38	*Calotropis gigantea* (L.) Dryand.	✓	✓	✓	✓	✓	✓
39	*Canna indica* L.	✓			✓	✓	
40	*Carica papaya* L.	✓				✓	
41	*Canscora diffusa* (Vahl) R.Br. ex Roem. & Schult.	✓		✓		✓	
42	*Capparis zeylanica* L.	✓				✓	
43	*Capparris grandis* L.f.		✓	✓	✓	✓	✓
44	*Cardiospermum halicacabum* L.	✓	✓	✓			✓
45	*Celastrus paniculatus* Willd.	✓				✓	
46	*Celosia argentea* L.	✓		✓	✓	✓	✓

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
47	*Centella asiatica* (L.) Urb.	✓					
48	*Chloris virgata* Sw.	✓	✓	✓	✓	✓	✓
49	*Chromolaena odorata* (L.) R.M.King& H.Rob.	✓	✓	✓	✓	✓	✓
50	*Chrozophora rottleri* (Geiseler) A.Juss. ex Spreng.	✓	✓	✓	✓		✓
51	*Cleome rutidosperma* DC.	✓					
52	*Cleome viscosa* L.	✓				✓	✓
53	*Coccinea grandis* (L.)Voigt	✓	✓	✓	✓	✓	✓
54	*Cocculus hirsutus* (L.) W.Theob.	✓	✓	✓	✓	✓	✓
55	*Cocos nucifera* L.	✓	✓		✓	✓	
56	*Colocassia esculenta* (L.) Scott	✓		✓	✓	✓	
57	*Combretum ovalifolium* Roxb.	✓	✓	✓		✓	✓
58	*Commelina benghalensis* L.	✓	✓	✓		✓	✓
59	*Commelina caroliniana* Walter	✓				✓	✓
60	*Corchorus sp.*	✓	✓	✓		✓	✓
61	*Cordia dichotoma* G.Forst.	✓	✓	✓		✓	
62	*Cosmos sulphureus* Cav.	✓	✓			✓	
63	*Couroupita guianensis* Aubl.			✓		✓	
64	*Croton bonplandianus* Baill.		✓			✓	✓
65	*Cryptolepis dubia* (Burm.f.) M.R.Almeida	✓	✓	✓		✓	✓
66	*Cryptostegia grandiflora* Roxb. ex R.Br.	✓	✓	✓		✓	✓
67	*Cullen corylifolium* (L.) Medik.	✓			✓	✓	
68	*Cyanotis fasciculata* (B.Heyne ex Roth) Schult. & Schult.f.	✓					✓
69	*Cyanthillium cinereum* (L.) H.Rob.	✓	✓	✓		✓	✓
70	*Cynodon dactylon* (L.) Pers.	✓	✓	✓	✓	✓	✓
71	*Cyperus scariosus* R.Br.	✓	✓				✓
72	*Dactyloctenium aegyptium* (L.) Willd.	✓	✓	✓		✓	✓
73	*Dalbergia melanoxylon* Guill. & Perr.						✓
74	*Dalbergia sissoo* DC.		✓	✓			✓
75	*Datura innoxia* Mill.	✓	✓	✓	✓	✓	✓
76	*Datura metel* L.				✓		
77	*Delonix regia* (Hook.) Raf.				✓		✓
78	*Desmodium tortuosum* (Sw.) DC.	✓	✓				✓
79	*Digitaria ciliaris* (Retz.) Koeler		✓	✓		✓	✓
80	*Dinebra retroflexa* (Vahl) Panz.	✓	✓			✓	✓
81	*Diplocyclos palmatus* (L.) Jeffrey.	✓			✓	✓	✓
82	*Echinochloa colona* (L.) Link	✓	✓	✓		✓	✓
83	*Eclipta prostrata* (L.) L.	✓	✓	✓		✓	
84	*Eichhornia crassipes* (Mart.) Solms	✓	✓	✓	✓	✓	✓
85	*Emilia sonchifolia* (L.) DC. ex DC.	✓	✓				✓
86	*Eucalyptus globulus* Labill.		✓	✓		✓	✓
87	*Euphorbia heterophylla* L.	✓	✓	✓	✓	✓	✓
88	*Euphorbia hypericifolia* L.	✓					
89	*Exacum pedunculatum* L.	✓					
90	*Ficus benghalensis* L.	✓		✓		✓	✓
91	*Ficus hispida* L. f.	✓		✓	✓	✓	✓
92	*Ficus racemosa* L.	✓	✓	✓	✓	✓	✓
93	*Ficus religiosa* L.	✓	✓	✓	✓	✓	✓
94	*Gliricidia sepium* (Jacq.) Walp.	✓	✓	✓	✓	✓	✓

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
95	*Glinus lotoides* L.	✓					
96	*Gmelina arborea* Roxb.						
97	*Gomphrena sp.*	✓					
98	*Grangea maderaspatana* (L.) Poir.	✓	✓				
99	*Grewia hirsuta* Vahl	✓					
100	*Grewia tilifolia* Vahl.	✓				✓	✓
101	*Gynandropsis pentaphylla* (L.)			✓		✓	
102	*Heliotropium indicum* L.	✓	✓			✓	✓
103	*Hibiscus sp.*		✓	✓			
104	*Holoptelea integrifolia* Planch.	✓	✓	✓	✓	✓	✓
105	*Homonoia riparia* Lour.	✓					✓
106	*Hygrophila auriculata* (Schumach.) Heine	✓	✓	✓		✓	✓
107	*Hyptis suaveolens* (L.) Poit.	✓	✓	✓		✓	✓
108	*Indigofera glandulosa* Wendl.	✓					
109	*Ipomoea aquatica* Forssk.	✓	✓				
110	*Ipomoea cairica* (L.) Sweet	✓	✓		✓	✓	✓
111	*Ipomoea carnea* Jacq.	✓	✓	✓	✓	✓	✓
112	*Ipomoea obscura* (L.) Ker Gawl.	✓					
113	*Ipomoea triloba* L.	✓	✓	✓		✓	✓
114	*Ipomoea nil* (L.) Roth					✓	✓
115	*Lagascea mollis* Cav.	✓					
116	*Lantana camara* L.	✓	✓	✓	✓	✓	✓
117	*Launaea procumbens* (Roxb.) Ramayya & Rajagopal		✓	✓		✓	✓
118	*Lemna gibba* L.	✓	✓		✓	✓	✓
119	*Leucaena leucocephala* (Lam.) de Wit	✓	✓	✓	✓	✓	✓
120	*Leucas biflora* (Vahl) Sm.	✓					✓
121	*Leucas longifolia* Benth.	✓	✓	✓		✓	
122	*Limonia acidissima* Groff	✓					
123	*Ludwigia octovalvis* (Jacq.) P.H.Raven	✓	✓	✓	✓	✓	✓
124	*Leonotis nepetifolia* (L.) R.Br.	✓				✓	✓
125	*Macroptilium atropurpureum* (DC.) Urb.	✓					
126	*Mangifera indica* L	✓	✓	✓		✓	
127	*Martynia annua* L.	✓	✓	✓		✓	
128	*Millingtonia hortensis* L.fil.	✓	✓	✓			✓
129	*Mimusops elengi* L.			✓			✓
130	*Mollugo pentaphylla* L.	✓					
131	*Morinda pubescens* Sm.	✓	✓	✓		✓	✓
132	*Moringa oleifera* Lam.	✓			✓	✓	
133	*Mukia maderaspatana* (L.)M.Roem.	✓	✓	✓			
134	*Muntingia calabura* L.	✓	✓	✓		✓	✓
135	*Neolamarckia cadamba* (Roxb.) Bosser	✓	✓	✓			
136	*Ocimum gratissimum* L.	✓					
137	*Oldenlandia corymbosa* L.	✓					✓
138	*Oxalis corniculata* L.	✓	✓	✓	✓	✓	✓
139	*Parthenium hysterophorus* L.	✓	✓	✓	✓	✓	✓
140	*Passiflora foetida* L	✓	✓	✓		✓	✓
141	*Peltoforum pterocarpum* Auct. non K.Heyne		✓	✓	✓	✓	✓
142	*Pergularia daemia* (Forsskal) Chiov.	✓				✓	✓

No	Botanical name	Zones					
		1.1	1.2	2	3	4	5
143	*Persicaria glabra* (Willd.) M.Gómez	✓	✓	✓	✓	✓	✓
144	*Phoenix sylvestris* (L.) Roxb.	✓	✓			✓	✓
145	*Phyla nodiflora* (L.) Greene	✓					✓
146	*Phyllanthus niruri* L.	✓	✓		✓	✓	✓
147	*Phyllanthus reticulatus* Poir.	✓	✓	✓		✓	✓
148	*Physalis minima* L.	✓	✓				
149	*Pistia stratiotes* L.	✓	✓	✓	✓	✓	✓
150	*Pithecellobium dulce* (Roxb.)Benth.	✓	✓	✓	✓	✓	✓
151	*Pluchea ovalis* (Pers.) DC.	✓		✓		✓	
152	*Plumbago zeylanica* L.	✓	✓	✓	✓		✓
153	*Polyalthia longifolia* (Sonn.) Thwaites		✓	✓	✓		
154	*Pongamia pinnata* (L.) Pierre	✓	✓		✓	✓	✓
155	*Portulaca oleracea* L.	✓	✓	✓	✓		
156	*Prosopis juliflora* (Sw.) DC	✓	✓	✓	✓	✓	✓
157	*Pseudarthria viscida* (L.) Wight & Arn.	✓	✓				
158	*Psidium guajava* L.	✓	✓				✓
159	*Pterospermum acerifolium* (L.) Willd.			✓			✓
160	*Putranjiva roxburghii* Wall.			✓		✓	
161	*Ricinus communis* L.	✓	✓	✓	✓	✓	✓
162	*Ruelia tuberosa* L				✓		✓
163	*Salix tetrasperma* Roxb.					✓	✓
164	*Santalum album* L.	✓	✓			✓	✓
165	*Senna siamea* (Lam.) H.S.Irwin& Barneby	✓	✓	✓	✓	✓	✓
166	*Senna sophera* (L.) Roxb.			✓		✓	
167	*Senna tora* (L.) Roxb.	✓	✓	✓	✓	✓	✓
168	*Senna uniflora* (Mill.) H.S.Irwin& Barneby	✓	✓	✓	✓	✓	✓
169	*Sesamum orientale* L.	✓			✓		✓
170	*Sesbania sesban* (L.) Merr.	✓		✓			
171	*Setaria viridis* (L.) P.Beauv.	✓	✓	✓	✓	✓	✓
172	*Sida acuta* Burm.f.	✓	✓	✓	✓	✓	✓
173	*Solanum lycopersicum* L.	✓	✓		✓		✓
174	*Solanum nigrum* L.	✓					✓
175	*Solanum torvum* Sw.	✓	✓	✓	✓	✓	✓
176	*Solanum virginianum* L.	✓	✓		✓		
177	*Sonchus oleraceus* (L.) L.	✓	✓	✓			✓
178	*Spathodea campanulata* P.Beauv.	✓	✓	✓			✓
179	*Spermacoce pusilla* Wall.	✓	✓	✓			✓
180	*Spilanthes acmella* (L.) L.	✓				✓	✓
181	*Spirodela polyrrhiza* (L.) Schleid.	✓	✓				
182	*Sterculia foetida* L.		✓	✓	✓		✓
183	*Synedrella nodiflora* (L.) Gaertn.	✓	✓	✓	✓	✓	✓
184	*Syzygium cumini* (L.) Skeels	✓	✓			✓	✓
185	*Syzygium heyneanum* (Duthie)Wall.ex Gamble						✓
186	*Tamarindus indica* L.	✓	✓			✓	✓
187	*Teramnus labialis* (L.f.) Spreng.	✓	✓				✓
188	*Terminalia arjuna* (Roxb. ex DC.) Wight & Arn.	✓	✓		✓		
189	*Terminalia catappa* L.		✓	✓	✓	✓	✓
190	*Terminalia cuneata* Roth						

		Zones					
No	**Botanical name**	**1.1**	**1.2**	**2**	**3**	**4**	**5**
191	*Themeda quadrivalvis* (L.) Kuntze						✓
192	*Tinospora cordifolia* (willd.)Miers.	✓		✓			✓
193	*Tithonia rotundifolia* (Mill.) S.F.Blake	✓					✓
194	*Trema orientalis* (L.) Blume	✓	✓	✓	✓	✓	✓
195	*Trianthema portulacastrum* L.	✓					✓
196	*Tridax procumbens* (L.) L.	✓	✓	✓	✓	✓	✓
197	*Triumfetta rhomboidea* Jacq.	✓	✓				✓
198	*Typha angustifolia* L.	✓	✓			✓	✓
199	*Urena lobata* L.	✓	✓			✓	✓
200	*Verbascum chinense* (L.) Santapau	✓	✓	✓		✓	
201	*Vigna radiata* (L.) R.Wilczek	✓					
202	*Vitex negundo* L.	✓	✓	✓			✓
203	*Wedelia triloba* (L.) Hitchc.	✓				✓	
204	*Withania somnifera* (L.) Dunal.	✓	✓	✓	✓	✓	✓
205	*Woodfordia fruticosa* (L.) Kurz	✓					
206	*Xanthium strumarium* L.	✓	✓	✓	✓	✓	✓
207	*Ziziphus oenopolia* (L.) Mill.	✓				✓	✓
208	*Zizipus mauritiana* Lamk.	✓	✓		✓	✓	✓

Annexure 3 : Checklist of recommended flora for plantations

(Refer Figure Typical cross section showing various habitats and the following links for habitats)
Native trees and their habitats http://oikos.in/html/newckfinder/userfiles/files/Grow_Natives_booklet.pdf
Plantation Guidelines refer to http://oikos.in/html/newckfinder/userfiles/files/PlantationsGuidelines.pdf

For Riparian Zone

Sr.No.	**Botanical Name**	**Local name**	**Sr.No.**	**Botanical Name**	**Local name**
	Trees			**Herbs**	
1	*Ficus racemosa*	Umbar	1	*Canna indica*	Kardal
2	*Pongamia pinnata*	Karanj	2	*Coix lacryma-jobi L.*	Kashed
3	*Salix tetrasperma*	Walunj	3	*Crinum viviparum*	Nagdamani
4	*Syzygium cumini*	Jambhul	4	*Cyperus difformis*	Lavhale
5	*Syzygium heyneanum*	Panjambhul	5	*Hygrophila auriculata*	Talimkhana
6	*Lagerstroemia speciosa*	Tamhan	6	*Persicaria glabra*	Paral
7	*Terminalia arjuna*	Arjun	7	*Saccharum spontaneum*	Ranus/Kamis
8	*Neolamarckia cadamba*	Kadamb	8	*Typha angustata*	Ramban/ Pankanis
9	*Acacia nilotica*	Babhul	9	*Centella asiatica*	Mandukparni
10	*Crataeva adansonii*	Varun	10	*Phyla nodiflora*	Jalpimpali
	Shrubs		11	*Baccopa moneri*	Neerbrahmi
1	*Vitex negundo*	Nirgudi		**Climbers**	
2	*Phyllanthus retuculatus*	Panjuli	1	*Tinospora cordifolia*	Gulwel
3	*Homonoia riparia*	Sherani	2	*Combratum ovalifolium*	Piluki
4	*Tamarix ericoides*	Kadesherani	3	*Argyreia nervosa*	Samudraskok
5	*Glycomsis pentaphylla*	Kirmira			
6	*Woodfordia fruticosa*	Dhayati			

For Upland habitat

Sr.No.	Botanical Name	Local name
	Trees	
1	*Alangium salvifolium*	Ankol
2	*Albizia lebbeck*	Shirish
3	*Bauhinia acuminata*	Pandhara Kanchan
4	*Bauhinia tomentosa*	Pivala Kanchan
5	*Bombax ceiba*	Katesawar
6	*Butea Monosperma*	Palas
7	*Capparis grandis*	Pachunda
7	*Cassia fistula*	Bahava
8	*Cordia dichotoma*	Bhokar
9	*Crataeva adansonii*	Varun
10	*Dichrostachy cinerea*	Sigamkathi/ Durangi Babhul
11	*Dillenia pentagyna*	Karmal
12	*Erythrina suberosa*	Buch pangara
13	*Ficus microcarpa*	Nandruk
14	*Gmelina arborea*	Shivan
15	*Madhuca latifolia*	Moh
16	*Magnolia champca*	Chapha
17	*Mimusops elengi*	Bakul
18	*Mitragyna parvifolia*	Kalam
19	*Morinda pubescens*	Bartondi
20	*Murraya paniculata*	Kunti
21	*Neolamarckia cadamba*	kadamb
22	*Nyctanthes arbor-tristis*	Parijatak
23	*Oroxylum indicum*	Tetu
24	*Phoenix sylvestris*	Shindi
25	*Pongamia pinnata*	karanj
26	*Pterocarpus marsupium*	Beeja
27	*Pterospermum acerifolium*	Muchkund
28	*Saraca asoca*	Seeta Askok
29	*Schleichera oleosa*	Kusum
30	*Sesbania grandiflora*	Agasti
31	*Tamilnadia uliginosa*	Pendhra
32	*Terminalia bellirica*	Beheda
33	*Wrightia arborea*	Tambada Kuda
34	*Wrightia tinctoria*	Kala Kuda
	Shrubs	
1	*Capparis decidua*	Nepati
2	*Carrisa congesta*	Karvand
3	*Clerodendrum phlomids*	Arni
4	*Helicteres isora*	Murudsheng
5	*Justicia adhatoda*	Adhulasa
6	*Pavetta crassicaulis*	Phapat
7	*Vitex nigundo*	Nirgudi
8	*Woodfordia fruticosa*	Dhayati
	Climbers	
1	*Argyreia nervosa*	Samudrashok
2	*Aristolochia sp.*	Badakwel
3	*Asparagus racemosus*	Shatawari
4	*Caesalpinia bonduc*	
5	*Cissus quadrangularis*	Hadjodi
6	*Clematis gouriana*	Ranjai
7	*Gloriosa superba*	Kal-lawi
8	*Hiptage benghalensis*	Madhumalati
9	*Oxystelma esculentum*	Dudhani
10	*Piper longan*	Pimpali
	Herbs	
1	*Bambusa arundinacea*	Kalak(Bamboo)
2	*Dendrocalamus strictus*	Mes(Bamboo)

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The Story of Jeevitnadi – A People's Movement for Living Rivers

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Introduction

In her book "This Changes Everything", award-winning journalist Naomi Klein argues that the crisis of man's relationship with nature, is an opportunity for new catalysts. These catalysts will often come in the form of spontaneous people's movements which bring people closer to nature, offer alternative economic models, and heal the man-nature relationship. Naomi Klein documents many such community movements in her book.

In Pune, we have Jeevitnadi, a homegrown people's movement to bring people closer to rivers and to revive rivers as natural ecosystems. Instead of being a short-term activist movement, Jeevitnadi has chosen the path of a long-term, peaceful and constructive movement.

To quote the authors of this article, "This is a journey of few passionate but mad people. All of them came from different backgrounds, very few knew each other. But a common thread, rivers, bound us together. Now it feels like a family. The magnitude of the problems of rivers did make us nervous at times but we did not deter from our cause. The river lies in our hearts and our heads start working to find ways. We all believe in the principle of restoration of rivers with a holistic approach. If our journey, our ups and downs, our highs and lows can motivate others to pursue their passion for protecting the environment, we feel that this story has served its purpose."

"We do not inherit the earth from our ancestors. We borrow it from our children"

Let's give our children what is rightfully theirs', a LIVING RIVER.

The beginning

The worsening condition of Mula-Mutha rivers in Pune city, the destruction of the Western Ghats, loss of biodiversity, degradation of soils are changes seen happening around us continuously. The news of these long-term changes was reaching us as citizens of Pune but failed to make an impact.

All of it changed after we completed the 1-year Postgraduate Diploma Course in Natural Resource Management, at the Ecological Society. Life was never the same again. We could not see anything in isolation anymore. All rivers that provide water to Pune city originate in the Western Ghats. Thus, we realized we owed our very existence to the Western Ghats. We could see all the hidden connections in nature. The faculty members at the Ecological Society made our life difficult in a way that made us grateful.

After this course, the condition of Mula-Mutha rivers began bothering us every day. We could no longer turn away and pretend nothing was wrong.

We all, the troubled souls, who would eventually form Jeevitnadi came together in 2014 and decided we were done being appalled. We wanted to do something. What that something was, we did not know.

We started meeting as a team every week. We discussed what we knew and what we had read. We met experts and shared our understanding with fellow learners. Taking Prof. Prakash Gole's 1982 report on the state of rivers in Pune as the base, we decide to study it, assess the current situation, create a plan applicable to the present conditions, and eventually present it to the Pune Municipal Corporation (PMC).

Once a definitive plan was in place, everybody started working towards it. Usually, an organization is formed, a structure is defined and then people are hired to fit that structure. On the contrary, Jeevitnadi started as a group of like-minded people, passionate about river revival. Structure and roles emerged along

the way. This 'organic' development has propelled us forward. Passion always was and is the force that is the primarily driver at Jeevitnadi.

This lack of structure created a lot of ambiguity as well. It allowed some members to be creative, while some members found it confusing. After the exciting initial start, we lost several members over time. Members who expected a definite plan or a clear-cut agenda, got discouraged and left Jeevitnadi.

Though disheartening, this phase also saw new leadership emerging. Members spontaneously took up various tasks. The "Lateral leadership" model defined a distinctive path for Jeevitnadi.

The best part about the lateral leadership was that we realized everyone had started taking responsibility as per the skills and proficiency they possessed. This provided space and freedom of expression to each member who was dedicated to the cause.

Awareness Generation work

Our understanding increased with each weekly meeting and self-study. We introspected on our plan. The river restoration plan prepared by Prof. Prakash Gole was comprehensive, cost-effective and easily implementable. Yet, it had not seen the light of the day. This created some doubts about whether we would be successful in our journey.

At around the same time, some case-studies around the world made us rethink our strategy. E.g. The Clean Water Act in the US was born out of the huge public outcry that arose due to Cuyahoga river catching fire. Local citizens had realized gravity of the situation and decided to do something about it. A similar pattern is observed around the world. Unless citizens are involved, no government scheme alone can revive a river. Rather, government policies are often an outcome of citizen movements.

e.g. In Pune, Dr. Narendra Dabholkar began advocating people not to immerse Ganesh idols in the river, back in 1980s. This was deemed unthinkable at that time. Eventually, Pune Municipal Corporation (PMC) supported it and provided water tanks for immersion at Visarjan ghaats. Today, even the important idols of Maanaache Ganapati do immersion in the tank and not in the river, doing away with 125 years of tradition.

Thus, we had become sufficiently convinced that river revival is not possible without active participation of the citizens. What use is any conservation plan, if apathy towards river remains as it is? It is again money down the drain, just like so many Nadi Sudhaar schemes and Action plans.

A river faces various challenges in an urban landscape : Liquid pollution from point and non-point sources, solid waste, construction debris getting dumped in the riverbed, industrial effluents, infestation of invasive species like Water Hyacinth and Pistia, encroachments on the riverbed, loss of riparian vegetation, channelization, soil capping etc.

Often, corrective measures focus on the symptoms, rather than causes. One tends to analyze it as a problem which is visible and is a symptom. The course with the Ecological Society had taught us to analyze problems and look at the root cause(s).

At this point, all our analysis led to an overwhelming sense of challenges. If we wanted to act, exactly how and where should we start, we wondered.

Answer to this question came from Dr. Pramod Moghe, an eminent retired senior scientist from National Chemical Laboratory. We learnt from him that around 70% pollution in majority of our rivers is domestic i.e. it comes from our houses. He explained vicious cycle of chemicals as shown in Fig. 1.

We citizens use various chemicals through daily-use products like toothpaste, shampoo, soap, detergents utensil cleaners, floor cleaners. Majority of these chemicals are toxic and are linked with different disorders. Many of them are human-made. They do not disintegrate in nature. The established Sewage Treatment Plants (STP) generally cannot remove them. In fact, the STP plants' functioning capacity reduces because of these chemicals. Once let out in the environment, these chemicals will be here, probably forever. The chemical-laden river water is used for irrigation downstream. Chemicals in the water enter soil and are absorbed by crops growing in that soil. Thus, the same chemicals that we use and flush from our house with water, land back in our food plate through grains and vegetables.

The harmful chemicals eventually contaminate groundwater too, which gives rise to an entire set of different issues.When citizens discuss river pollution, we tend to blame it on the industry and the agriculture. We feel these two are solely responsible for pollution. Interactions with Dr. Moghe opened our eyes to our own role in river pollution and provided a definitive direction to Jeevitnadi. We had never anticipated that the problem would be so complicated and serious! We passionately felt we had to do something about it.

Each individual uses around 0.04 kg of chemicals every single day. For a city of size of Pune city, that is 0.4 x 50 lacs = 2 lac kg of chemicals in the river everyday. Herein lay a positive challenge: If 70% of the river is polluted because of us, then it also means we can keep it clean up to 70% through our actions.

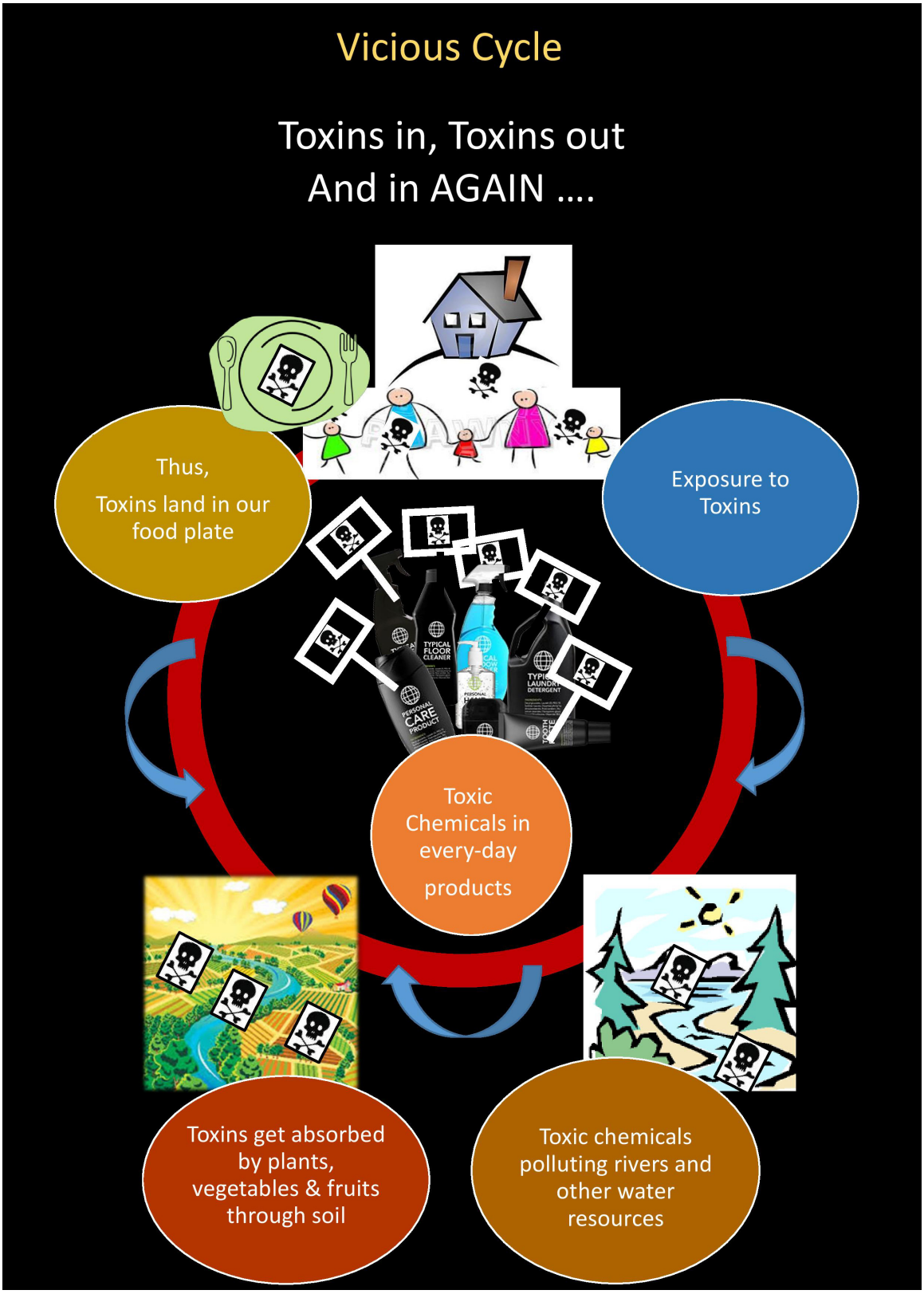

Fig. 1 : Vicious cycle of chemicals

Thus, we decided to focus on "What I can do for my river, as an individual" by adopting Toxic Chemical-free Lifestyle, as a theme for our communication with mainstream citizens.

We had a plan and we started execution. The objective was to reach a large number of people and generate awareness about Toxin-free Lifestyle (TFL). We started reaching out to various organizations, educational institutes, corporates, citizen groups, and housing societies with Toxin-free Lifestyle sessions.

TFL is now Jeevitnadi's oldest running program. By now, it has reached many people across India.

A few colleges have come forward to take TFL under their curriculum and are running since last year. In this interaction, we noticed that curricula of schools or colleges does not provide any knowledge about life cycle assessment of any ingredient which is used in day to day lifestyle personal care or hygiene products. Neither do we have any on-the-ground practical applications about the river environment or the importance of ecosystems.

These experiences made us realize the challenges in increasing awareness. How does one approach such a multi-level, multi-dimensional and complex issue such as improving the health of our rivers? Unless a citizen is at least partially aware, how does one approach to make them understand the gravity of the issue?

Necessity is the mother of invention. We knew that we had to either look for success stories about river revival or we needed to invent a new wheel. By whatever means we undertook the work of educating the masses about importance of river ecosystems, under a holistic approach.

We came to know about "World River Day" which is celebrated in many places all over the world. It is on last Sunday of September. The concept of celebrating the river immediately touched us. The creative minds in our group started playing with different ideas to celebrate the World River Day. Though initially we were against any type of event, we realized interaction around the river is as necessary as the conservation activities.

We celebrated Muthai River Festival, for the first time in 2015 on "World River Day". The idea was to celebrate our river. This type of activity was probably happening for the first time in Pune. Such interaction is a necessary first step towards conservation.

It is known that there were 14 ghaats along Mutha river in the 1 km stretch between Lakadi Bridge to Mula-Mutha sangam. Ghaats are a set of stone stairs that facilitate easy and safe access to the river. The number of ghaats is thus a proxy for the interaction

Muthai River Festival

this city used to have with its river.

We decided that instead of always discussing issues and problems, we will bring people to the river for some action and fun. The concept was a huge success. The diverse set of activities, including 15-minute cleanup, Paint the river, Saritayan, the music program with river as the theme, "Story of a River" exhibition, and all such programs (many of them done at the ghaats, facing the river) saw a phenomenal turnout and excitement.

Muthai River Walk, now a signature activity of Jeevitnadi, was also launched as part of this festival.

Since 2015, the festival has continued in the same spirit. All the events are planned with focus on bringing people of varied ages and varied backgrounds to the river. The different themes explored every year bring in more angles of interaction and more thoughts. The River Festival has become a good platform for forming associations with schools, colleges, corporates, other NGOs etc. This has further brought new talents in our folds, opening new avenues.

For example, there are multiple NGOs and citizen groups working on the river in Pune itself. But they did not have a uniform agenda, everyone worked in pockets, so the result or impact was not seen. We had been realizing that we need to harness this energy together. It would also create a pressure on government authorities for better environment management. Last year, our efforts were met with a huge success. About 21 organizations working on river coming together to celebrate "India River Day". A huge clean-up drive was organized on Mutha, Mula, Mula-Mutha, Indrayani & Pawana rivers on a single day. All the participating organizations agreed on a single agenda where there was no ambiguity: "Solid waste-free rivers of Pune with a Mission 2020". This also got aligned with Pimpri Chinchwad Municipal Corporation (PCMC) and Pune Municipal Corporation's (PMC) agenda of "Swachh Bharat" mission.

PMC and PCMC have huge resources and infrastructure. The regions under these municipalities are the major polluters too. It was imperative that we should engage and get them on board. Last year, the Muthai Festival hosted an exclusive River walk for PMC Commissioner, the Mayor of Pune and all senior administrative staff of PMC to sensitize them about river. PMC came out in a big way to support and celebrate the cause of river. For example, they took Department-wise River Walks. This gave us confidence to deal with the authorities which we lacked before. Within PMC, it gave them a confidence that Jeevitnadi is willing to work on participatory solutions. From an organizational point of view the events helped us to form great associations with others. Now when there are meetings to evaluate PMC or PCMC policies on rivers, all the organizations voice the same agenda. Jeevitnadi has become a facilitator to bring in the various active groups.

However, the challenge of Solid waste Free Rivers of Pune by 2020 seems to be a very tough target. At this juncture, it looks very hard to achieve. This opens new doors of scaling up differently. New ideas are coming in, but we are yet to develop specific plans for some of the ideas.

We also launched "Storytelling by the River" and "Events by the River", extending Muthai River festival's essence. Kids sitting by the river, listening to stories is a heart-warming sight. We organized these programs on the banks of Mutha, Mula, Mula-Mutha, Pawana (on much demand from Pimpri-Chinchwad residents), Mula-Ram confluence, in association with our favorite storyteller, Vaishali Kulkarni of The Story Station. Events by the river comprised of Street play, Music programs, Poetry programs, Sketching by the River etc. Again, our motive is to attract all age groups.

At the end of Storytelling program, we see kids clicking selfies with the river. The river that was not present in their mind earlier, now feels important enough to click a photo with. A baby-step no doubt, albeit it takes us one step closer to our goal.

The Muthai River Walk was launched on 4th October 2015, in partnership with Janwani, a leading NGO in Pune. It heavily derives from the concept of heritage walks. It is unique due to its theme being the river. In this half a kilometer stroll along the Mutha river, the guide covers archaeological history, the river ecosystem, how the city of Pune got established in the cradle of the river, how the city changed the river and how city in turn was shaped by the river, and landmarks along that stretch. Similar walk has recently begun at the confluence of Mula and Ram rivers.

Right from planning this walk, selecting the stretch to creating the script was a challenging task. The idea is that a participant who is presently looking at smelly, turbid river must go back with a positive attitude, a basic yet holistic knowledge of the river and an urge to do something for the river. We decided that we will create a story which starts from ancient history of civilization to the current transformation. Dr. Sharad Rajguru, who is an expert on the Mutha river and its archaeological history, provided us all the inputs for the pre-historic period. Prof. Prakash Ghanekar's book "Muthekathche Pune" helped us understand our own city and it's past. Dr. Swati Gole helped us refine the

river ecology portion of the walk.

The resulting script for the River Walk has mythological stories, ancient history of civilization, natural and cultural historical evidences, entry of humans, agriculture, important ecosystems and processes of a river, socio economic aspects, geology, geomorphology all woven in a very interesting story. The River Walk has been an outstanding, rich, and inspiring product resulting from collaboration among Jeevitnadi team members and experts. Our team members are never tired of being guides for these walks. The River Walk has been a continuous year-round activity except a few rainy days and has proved to be most successful tool of awareness in an urban community. Urbanites are short of time and are generally stressed with their own priorities. But taking out just 90 minutes on a Sunday morning without disturbing the day's routine proved convenient to them. The location where the walk begins is centrally located and easy to reach. All these factors contributed to the appeal of the River Walk. For Schools and Colleges, we provided a choice of Saturday mornings for River Walks. Soon the River walks became part of several school and college curricula.

The River Walk starts with a simple question, "How old is the Mutha river?" It is baffling for the participants because nobody has ever given much thought to the river. 50? 100? 300? 1000 maybe? answers come as hesitant guesses and whispers. When we end the suspense and tell them that the Mutha river is minimum 1 crore (10 million) years old, the reactions are amazing. It automatically implies the fact that the Mutha river does not flow through Pune city, but because of the river, conditions were just right for a city to be established here. This realization completely changes perception towards the river. We immediately see a change in participants' attitude.

Outcome of such awareness-oriented initiatives are often not tangible and cannot be expressed as hard numbers. We assess its effectiveness with the fact that since its launch, this walk has been conducted for numerous schools, colleges, organizations, corporates, citizen groups, and individuals. Some city schools and colleges have made the Muthai River Walk a part of their curriculum.

Since 2018, we have introduced Nature Walk at Ram- Mula confluence. Once the participants realize the importance of natural flowing river, willingness to join the Nature walks is also seen. What they hear as part of the story during River walk at Siddheshwar Vrudheshwar ghaat, is witnessed at the confluence. So, relating with the ecosystem and its importance is like "seeing is believing". The Nature walk is usually extended as "Bird walk" during the bird migration period of December to March. Nearby schools and corporates find it very convenient to attend it. The outcome of such activities is further "feel good effect". They further participate in clean up, seed collection etc depending on availability of time. The group has also taken great efforts to map, identify and qualitative and quantitative assessment of flora within the river landscape.

Getting our hands dirty

After working as an informal group for 2 years, in 2016, we registered Jeevitnadi as a legal entity, making it Jeevitnadi – Living River Foundation. This gave our group a formal recognition as an NGO in the eyes of society and policy makers. We have always envisioned it as a people's movement and all our energy is put into taking it to that stage. We encourage all to replicate our concepts and successful projects. We call our fellow river activists and conservationists, as "River Warriors". Jeevitnadi is always in solidarity colleagues who are fighting for the river, though our ways might be different. "March Separate, Strike Together" is our favorite strategy.

For the first four years of its existence, Jeevitnadi focused primaily on "Awareness Generation". In 2017, a small experiment we conducted at Sambhaji Park in Pune revealed some interesting things that led to our first action-oriented project, "Adopt a river stretch".

We had worked with the assumption that people in general are indifferent to their rivers in urban areas. A new member to Jeevitnadi, a psychological counsellor by profession, suggested a few volunteers stand at various locations inside Sambhaji Park, which is truly a cross-section of our society, holding a chart that asks, "What do you think about our river?" She instructed us not to force anybody.

We were in for a surprise. 9 out of 10 people stopped and talked to us. They had so much to share and they were from all age groups. Even students who hailed from outside Pune shared their thoughts. Almost everyone wondered why the river is in such a bad condition. More importantly, almost everyone had a question, "What can we do for the river?" This was a great realization for us. It is not indifference, but it is helplessness that is keeping people away from the river and doing good for it. With this new-found knowledge, we launched the "Adopt a River Stretch" (AAS) program in May 2017 on Mutha riverbank at Vitthalwadi. The idea is to bring together people with "good intentions", back them up with solid ecological knowledge and convert those good intentions into concrete, meaning-

ful action towards river conservation. The Vitthalwadi project started with merely 3 members and grew into a large team. A similar project started in the same year, on the Mula riverbank at Aundh and Mula-Ram confluence at Aundh.

The year 2018 saw more stretches getting adopted, including outside Pune. A citizens group led by Mukund Bhagwat adopted a stretch of Ulhas river at Karjat. Rohit Saha, a River warrior started working on Vedavati river at Khatav in Satara district. Swati Dixit, another river warrior started work on Meena River at Narayangaon. Queries are also coming from all over the city of Pune. With success of "Adopt a stretch" citizens are realizing they can do something for the river in a personal capacity. However, as Jeevitnadi members, we are facing some logistical and manpower challenges, which we soon hope to overcome. The implementation of "Adopt a Stretch" made us aware of ground realities, complexity of issues, and interlinkages of many of those issues. It opened our eyes to the tremendous challenge haunting the local governing bodies and irresponsible behavior of citizens.

The Vitthalwadi stretch project started in May 2017. We had been picking up accumulated garbage which included a variety of items like pillows, clothes, footwear, bags, stationery, packaging material, condoms, sanitary napkins, diapers, frames, plastic bags, disposable crockery and cutlery, food items, and so on.

As fast as we cleaned up, more garbage would show up on the riverbank. Everybody wondered for how long we are to do this. The team members' morale was down. However, from January, we sensed the change. With each passing Sunday, the amount of garbage dumped in the riverbed began to reduce. As we cleared years of years of accumulated garbage and the riverbed started to look clean, the tendency of garbage dumping too decreased. We believe there is a psychological factor in this. When there were heaps of accumulated garbage, people felt justified dumping more, but nobody wants to be the first one to litter a clean place. The clean riverbed itself acted as a deterrent, even when none of us were present to advocate against dumping. This was an important learning which also paved the path for some future projects like Wetland Development.

The Mutha river has many feeder streams ('odha's). Ambil and Nagzari are some of the major feeder streams. Along with them, many relatively smaller streams do exist, the ones that are not yet lost to encroachment.

Channelization of Mutha river happened in phases, since the 1960s. The sewage pipeline was laid parallel to the river, in the riverbed. All these interventions resulted in topological changes to the riverbed. Many streams now do not reach the river in a natural flow. They result in a series of stagnant pools in the riverbed. Such stagnant pools breed mosquitos and create foul

Muthai River Walk

smell due to anaerobic conditions. These pools eventually attract garbage. These conditions create a perception of the riverbed as something dirty and unhealthy. Due to these conditions, people turn away from the river.

With validation from Oikos for Ecological Services and under the guidance of Lemnion Green Solutions, we implemented a pilot project for a small but perennial stream at Vitthalwadi. The idea is to join these stagnant pools, let water pass from one pool to the next, thus reaching the river and treat this water with the help of soil and plants along the way.

This project earned us many volunteers. People, especially the young generation loved the action. Their energy and enthusiasm saw us through many unexpected challenges. Once completed, this intervention completely changed the look of the river stretch. Water was now odorless, clear and its Dissolved Oxygen (DO) turned out to be 5.5 ppm. (DO of river is in the range of 0 to 2 ppm except for monsoon months).

Among other benefits of this exercise: Sound of the flowing water is soothing to ears. It attracts people to the stretch; it creates a beautiful image of the river and the riverbed. With success of the pilot and some valuable experience to boost our confidence, we replicated it for a relatively larger stream in the same stretch. Our experienced and equally enthusiastic members -- we call them "Wetland Task Force" -- are ready to tackle this same challenge, at other places in Mutha riverbed as well as in Mula and Ram rivers.

The river being a "common resource", everybody has a right to it, but no one has responsibility. This project is instrumental in creating a sense of responsibility towards our rivers. "Adopt a River Stretch" and "Wetland Development" involve working at a specific stretch of the river for a period of time. This has created a close bond of team members with the river. "My River, My responsibility" is the way they feel about the river. Ground realities pose different challenges at every stretch. Though every stretch has some common problems like presence of solid and liquid waste in river, encroachments, debris dumping etc, it also has different challenges.

In August 2017 two members of Jeevitnadi decided to adopt Ganesh Ghaat near Rajiv Bridge on Mula at Aundh. It has a pristine bank towards PCMC side, being in defense department's boundary. On the PMC side the riverbank is extremely stressed as the villages of Aundh and Baner, have become hotspots of huge construction activities and developments. The villagers who were once dependent and connected with the Mula river once have turned their backs to the river. They have become indifferent and careless. The fishermen whose livelihood depends on Mula also look only for short term profits. Locals use this place as a spot for drinking and all sort of illicit activities.

It is said that "Old habits die hard". When the local population was not as much as it is today, throwing nirmalya (old and stale flowers from worship) into the river, idol immersions, and feeding fishes by throwing leftover food was a common practice. As population has ballooned and the city boundaries have extended on both sides on PMC & PCMC, dumping of solid waste has become a common feature for Mula as the river is accessible from two different bridges while driving through. Our first challenge was to stop the practice of throwing nirmalya and garbage. Yearlong awareness campaigns on the bridges resulted in installation of two compost pits for nirmalya in two temples. Jeevitnadi was able to get two donors who paid for these compost units. These units are being used actively by people for depositing nirmalya. Now we are pursuing the authorities that they should install such units at every religious place along the riverbanks. This will save huge amount of nirmalya going into rivers. The habit of throwing nirmalya in river is an old practice and even today's generation prefers to continue it, as they don't want to get it mixed with other solid waste at home. Our solution of compost pits respects these sentiments. We hope that both PMC & PCMC take steps for managing religious worship materials at the religious places itself. This will reduce the amount of such material going into rivers.

Similarly, after funeral rites, material like flowers and food is often sacrificed directly into the river. We are also trying to persuade authorities for provisions to accept such material at Smashan Bhoomi (crematoriums) of every area. "Events by the River" brought in new volunteers. Now the group's strength is increasing. Regular clean ups and vigilance has made a difference. The PMC Solid waste staff also took notice of our regular visits and they work with us every week. Once neglected, the ghaat with two beautiful heritage structures now looks clean and neat. The team has also planted a few native saplings. They have kept a track of the type of solid waste thrown and the amount of solid waste collected every week. Photo documentation of this progress has been created. Gradually the fishermen are getting connected with us and the river. Now virtually every person of Aundh gaon knows Jeevitnadi is working on Ganesh Ghaat. Though they do not yet come out to help, they spread the word. Two years consistent and tireless efforts have started bearing fruits slowly in gaining confidence of locals.

The Ram-Mula confluence stretch was adopted at around the same time by a group of residents staying in the area. This pristine patch faces a very different challenge. The area is in the flood plains of 3 rivers – Devnadi, Ramnadi & Mula. The green belt along the bank is extremely rich with flora and fauna. Until recently, the village of Baner had agriculture fields in these flood plains. With the increase in urbanization, land use changed, and huge constructions started coming up in Baner and nearby area, which are now deemed Pune's 'suburbs'. The frequent and careless dumping of debris is a major problem now. Additionally, the Baner Sewage Treatment Plant (STP) right at the confluence poses a challenge to water quality and is a huge threat to flora and fauna and their habitats in and around the rivers.

Thus, the top priority was to establish and protect the area as a green zone. The team's constant vigilance and repeated letters to authorities brought in some change. The dumping of debris has stopped currently but existing debris have not been removed from the location. Now that our efforts are recognized by the PMC, we insisted that the PMC Commissioner must visit all the stretches where Jeevitnadi is working on and see the state of the river with his own eyes. We were successful. The PMC Commissioner Saurabh Rao spent an hour on each stretch understanding the threats to the rivers.

At the pristine patch in Baner, the team had an opportunity to observe and document every seasonal change happening in the river. This has created good background data over the last two years. Without any expert to lead them, volunteers learnt the importance of observing flora and fauna by experiencing it on ground and documenting the same. This led to fact-based decisions and positive results. Due to the constant vigilance and protection by volunteers, the Green cover is increasing in spite of heavy debris. Day by day, the fallow land (left vacant after end of agriculture in the area) is getting converted into green cover.

Extending the awareness efforts further, we have now tapped into the talented pool of school and college students in Pune. We understand that not everybody can come to the river regularly for work. We envisioned that students could participate in river conservation using their education and diversity of skills. It could be mobile app development, making devices for river cleaning, digital visualization of ecological riverfront development, peer to peer learning, participation in art performances related to river and so on.

We would get fresh ideas and students would gain experience of real-life project and satisfaction of having their idea implemented. Along the way, we create future citizens that are sensitive to their environment.

The story continues

We are sometimes asked about the organization structure at Jeevitnadi. Apart from the formalities required from a legal entity, there is no hierarchy in Jeevitnadi. Team members bring in ideas, others help them refine it and that idea is taken to execution through everybody's effort. All our members are foot soldiers. Though our focus is to take along everyone to join this mission, we will also firmly stand against projects that cause ecological damage to the river. When we came to know that River Krishna is getting concreted right in riverbed at Wai, we decided to be an applicant to the National Green Tribunal (NGT) against Wai Municipal Corporation. NGT's verdict went against WMC and they were ordered to pay a fine of Rs. 25 lacs. WMC went into Supreme Court, which also maintained the same decision and ordered WMC to treat the drainage properly by using this money and rectify the damages done to the river. The case has given us confidence: If you know you are right and if you are able to prove it too, you can make a difference. But we feel Jeevitnadi alone cannot be at all places. We need to inspire hundreds of Jeevitnadi kind of organizations coming forward in every village, every city, every state.

All our efforts seem a mere drop in the ocean when we consider the magnitude of the challenge. However, one thing is certain, we are successful in uniting all people who wanted to do something for the river, who felt lonely and helpless on this path. We are confident this community of river warriors will inspire many more and will provide them knowledge and courage to stand for their rivers.

As Baba Amte says,

"त्या तिथे वळणावरी पण वेळ क्षण एक आला
एकटे एकत्र आले आणि हा जत्था निघाला"

Along the way, came a turn, where lone crusaders came together, and a procession was formed.

Case Study 1 :

Wetland Development Through Community Collaboration for River Conservation

Background

Jeevitnadi believes that river restoration and revival is not possible without active participation from citizens. This led to the 'Adopt a Stretch Program', launched in 2017.

At the adopted stretch at Vitthalwadi on Mutha river, we spent the first several months simply cleaning the riverbanks. But to change the urban perception towards the river, we needed to do something more.

Location : Around 1 km, the stretch spans both sides of the Pundalik Temple. The riverbank has a history of 175+ years of human use. There are two 'gomukh' (sculpted cow-heads in stone) which continually discharge water. Gomukh is a structure through which water of a live spring flows into the river. It is a traditional practice of water conservation across India.

Stresses : The stretch represents all the stresses the river has in an urban landscape.

- In the decade of 2000-2010, various interventions happened in the riverbed. The river was channelized.
- A sewage pipeline was laid along the river. Beautiful basaltic rock in the riverbed was blasted to make way for it. Those rocks were dumped in the riverbed.
- Over the years, silt carried by flood waters accumulated in these rocks. Several mounds were formed, blocking path of water to the river. There are many such marshy formations in the riverbed. Though they too are habitats, they are not part of the original character of the riverbed. Due to these blockages, water that should have reached the river, resulted in stagnant pools in the riverbed.

Impacts :

- The river is deprived of fresh water.
- The stagnant pools breed mosquitos and stagnation cause the water to stink.
- People perceive riverbed as an unhealthy and stinky place and avoid it.
- Since it becomes a neglected place, garbage dumping in these pools became rampant.
- This results in a vicious circle of destruction of the river.

Stagnant Pools, With Dumped Garbage Before Project

Restoration Approach and Plan : The first year was dedicated to observation, documentation of water flows and biodiversity, understanding various environmental impacts, sources of pollution, observing human interaction with the river, etc.

Based on such observations we decided on the following :

1. We will start small i.e. Implement a plan on a small scale.
2. We will learn and make course-corrections.
3. We will then replicate this experience for other pools.

We wanted to not disturb the natural integrity of the wetland, but help it to sustain by shaping, sizing and streamlining it. We decided upon restoration work on four pools adjacent to the riverbed.

Thanks to our enthusiastic volunteers and experts such as Lemnion Green Solutions and Oikos for Ecological Services, we embarked with a restoration plan which needed work on six Sundays.

We decided to join the 4 pools by digging passages in between. Thus, we would make water flow from Pool 1 to Pool 2 to Pool 3 to Pool 4. From Pool 4, water would flow into the river. Some marshy vegetation was already present, which would aid in water purification. We enhanced its role by planting some more. Duckweed in the pools further helped in purification.

On each Sunday, we used to decide a set of tasks for each pool and share with the team

Results

- The project went as planned. After week 4 of the project, water started flowing out of Pool 1. Water in this newly created wetland system was clear and had a natural character. The foul smell has vanished.
- The growing duckweed and presence of pond skaters, which are integral part of a healthy wetland, assured us that we were on the right track.
- During week 6 a group of passer-by kids cheered and went to the clear, flowing water. They go biking every Sunday and confessed that they used to pass this stretch, but never felt like coming to the river until that day.
- This wetland is now home to crabs and fish. Various birds visit it from time to time.

With this experience, we embarked on a second project and successfully completed it for a stream in this same stretch. We have started work to replicate this approach for other such places along Mula, Mutha and Ram rivers.

Flood Fury of Pune : Understanding the Tributaries

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Rationale

On 12th July, 1961 Pune city faced devastating floods due to collapse of the newly constructed Panshet dam and breach of Khadakwasla dam. The dams emptied within a few hours that day. There was a total devastation in Pune.

A catastrophe such as dam collapse is a rare phenomenon. But it will not be an exaggeration to say that we got a glimpse of it, in the form of floods of 2019. Floods in the Ambil odha, a major feeder stream to Mutha and in the Bhairoba nalla, a major feeder stream to Mula-Mutha caused loss of life and property. The Settlements which suffered heavy losses were away from rivers and not in low lying areas. Bavdhan, Balawadi, Baner areas also suffered. These areas were also away from Mula river.

This made different experts related to water to look at the floods differently and emphasizing on River Ecosystems and its interventions.

Scope of the Article

This article does not cover the total span of Mula, Mutha and Mula-Mutha in detail. However, we have tried to take a holistic approach and correlating surface and subsurface water and morphological characters of sub watersheds in particular. All main rivers entering Pune region are dammed and their flows and floods are controlled by the dams. Stretches of river flowing through Pune city are joined by small tributaries and nallas. These tributary streams having large area of water shade contributes significant amount of water to the main river especially during rainy season to impact flow and floods in the Pune city. The recommendations provided in this article are based on various scientific investigations done over various periods, on various subjects in the area and region. The article is a narrative of the causes and suggests solutions for controlling and minimising flood impacts in Pune city and the region around Pune.

The scope of this article is limited to Pune city :

1. Case study of Ambil stream – a tributary of Mutha
2. Case study of Ramnadi – a tributary of Mula

All instances of the causes cannot be covered here. It is beyond the scope of current article. But it could be representative of the current scenario of floods and impact of climate change.

About Pune Rivers

Pune is blessed with five rivers and multiple sub watersheds beyond their catchment areas. All create multiple confluences in and around Pune. Mula is a major river flowing through the city. Its drainage density is intrinsic. Dev nadi, Ramnadi, Pawana River and Mutha river confluence with Mula creating rich ecosystems. However City's development has put pressures on Mula Mutha confluence and Mula Pawana confluence. The rich biodiversity of these rivers has taken a toll due to city's development and land use change. However area around confluence of Devnadi and Mula River and Ramnadi and Mula River still boasts a rich biodiversity and ecological processes. Tributaries play important role in Riverine ecosystem.

Importance of the confluence of River and tributary

Until recently the confluence of tributaries has received less attention. However the perception is changing. Increasingly it is known now that confluences not only alter ecological responses and elicit a biological response in the channel that they join but also because

of tributaries confluence zones are sites of intrinsic ecological value where particular biophysical processes and ecosystem services may be concentrated. This intrinsic ecological value of confluence zone extends beyond channel on the river banks.

Important functions of tributary confluences :

1. they are important sites of increased biological productivity due to tributaries bringing the nutrients and type of sediments they carry
2. Confluences are located juxtaposed ideally connecting upstream, downstream and become continuum between tributaries and river's biotic system. This supports the Biodiversity of the area in stream and along the banks.
3. Morphological characters and hydraulics of confluences create variety of habitats to provide ecological opportunities for some organisms.
4. The main river channel near the confluence of tributary streams adjusts its physical setup with the influx of water and sediment provided by tributaries. This adjustment results in heterogeneity in the physical conditions and enhances habitat diversity with wide array of environmental conditions. This is likely to enhance habitat variability.

Understanding floods

The primary function of the rivers is to carry water in the form of flow. The average level of flow in the channel of any river depends on several factors such as amount of rainfall received in the watershed, contribution of ground water through springs, stretches of channel losing water by contributing to aquifers etc., similarly flood flows which are above the channel spreading on the banks also depend on complexity of these factors, such as number of rainfall events intensity of rainfall as well as morphology of the watersheds.

Floods are looked at negatively because; they devastate settlements, bring misery to human lives, disrupt cities, and incur financial losses to the nation. All of these were evident in Pune in the months of August and September 2019, when the city experienced unprecedented flooding in its rivers. A preliminary analysis of the floods reveals that it was not just the fury of nature that wreaked the havoc, but a significant part of the problem was due to human interventions which changes the physical set up of the well-defined river channels and the banks, resulting in disturbances of ecosystem. This article tries to throw light and try to understand the real causes of floods in a holistic manner, considering the river as a continuum and a living ecosystem.

In the last few years, urban flooding has become a frequent phenomenon. Nearly every city is vulnerable to urban flooding in some way, and the residents are at high risk. In cities, vegetation cover along the banks is removed and area of bare soil have been converted into built up hardscape areas, leaving little space for water to percolate and increase in the surface runoff. As a result, most of the rainwater runs off the hardscape, resulting in pluvial flooding or urban flooding. With the rapid increase in impermeable surfaces with increasing urban sprawl, the risk of flooding increases significantly. Furthermore, the urban floods are more lethal with the intensification of rainfall. The risks of urban flooding are expected to increase with changing climate.

(https://www.teriin.org/climate#:~:text=The%202019%20report%20by%20the,%C2%B0C%20of%20global%20warming.)

Such urban floods are amplified by man-made interventions. The risk of such high intensity urban floods can be reduced and controllable by proper planning.

This article recognizes the need for integrated flood risk management and resilience to flood risk which includes enhancing the capacity of people and communities to adapt to and cope with flooding. The Holistic approach mainly focuses on ecological restoration and rejuvenation of the rivers, policy interventions and measures in governance.

Naturally occurring floods in a river ecosystem involve bank area along the river that is seasonally submerged. Due to human interventions in the natural physical riverine structure and related ecosystem, flood risk increases. Though these flood lines are well marked, based on the historical floods that occurred, the development inside these flood lines should be restricted adhering to principles, guidelines and norms that are made from time to time (http://punefloodcontrol.com/maps.html).

The reasons of natural flooding differ from one city to another as climatic parameters and morphological parameters of the watershed differ from one city to another. Documentation of few instances of natural flooding are recorded in the Pune city over the past few decades. This documentation will be of use to assess unnatural flood events.

Types of flows

Flood mitigation measures will largely depend on understanding type of flows as shown in Fig. 1. If we understand type of flows, we can understand mitiga-

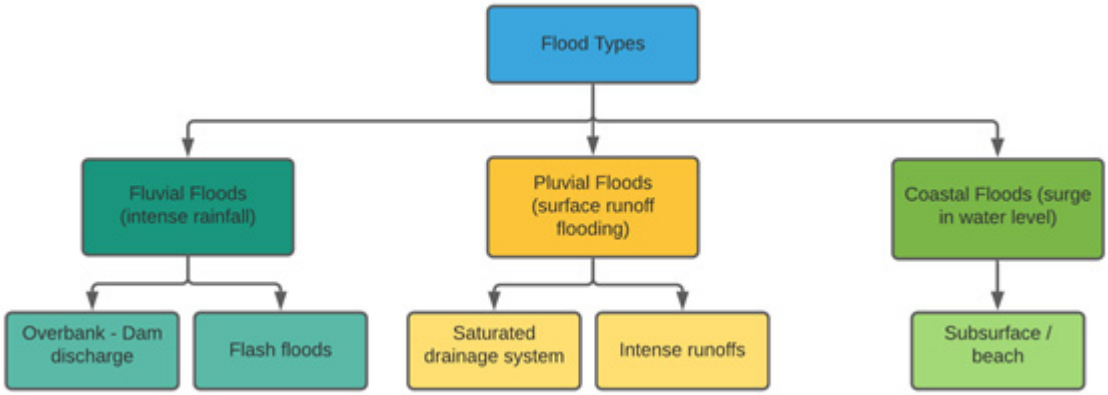


Fig. 1 : Types of Flood

tion of floods.

Types of Flows :

1. Surface flow / Overland flow / Horton's flow
2. Subsurface flow- just below the soil layer
3. Groundwater flows in the form of springs
4. Rains directly falling into river and stream channels or in a city.

Out of these four types of flows, first one that is overland flow may become much severe due to increase in hardscape area in the city. In absence of soil cover, subsurface flow will significantly reduce. This will reduce capacity of recharging of the aquifers. Similarly, because of hardscape ground water recharge will be less and so is the ground water flow. This situation

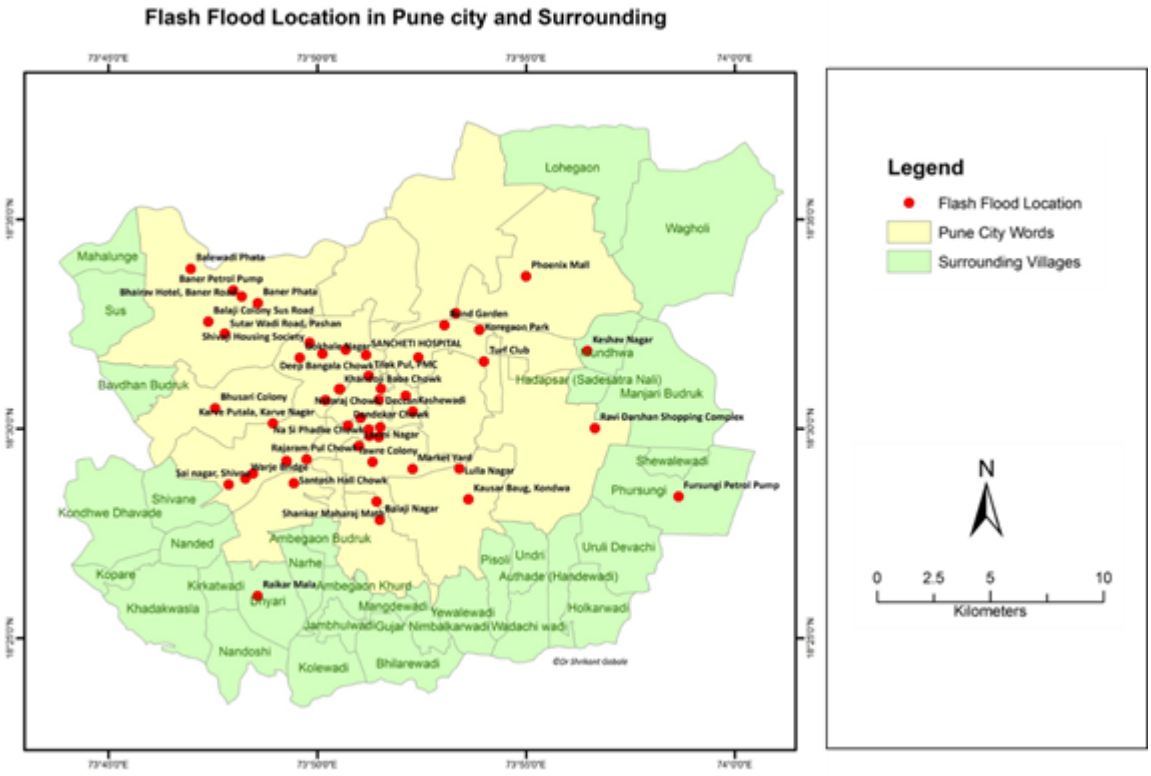


Fig. 2 : Map by Dr. Shrikant Gabale

favours overland flow, significant amount of rain water then flows as flood water forming as "Pluvial "unusual flood. The character of rainfall event is also changing because of climate change, becoming more like a cloud burst. This will increase impact of each flood event many folds.

Types of floods

River flooding is classified into three types (Figure ..)

Flood fury of Pune

Fluvial flooding is caused by high intensity rainfall. Overbank flooding inundating settlements occurs when water flows over banks of the river. The other type of flood event can happen when dam reservoirs are to their full capacity, while heavy rainfall events continue. In such a situation large quantities of water are released causing artificial floods. Flash flooding is characterized by an intense, rapid gush of water that occurs sporadically. This poses threats to urban settlements.

Flash floods in Pune

Urban flooding is mainly due to a disturbed drainage in an urban area. As there is little open soil that can be used for water storage nearly all the precipitation needs to be transported to surface water or the sewage system. High-intensity rainfall can cause flooding when the city sewage system and draining canals do not have the necessary capacity to drain away from the amounts of rain that are falling. Water may even enter the sewage system in one place and then get deposited somewhere else in the city on the streets.

In Pune, during monsoon in the last couple of years, roads turned into rivers and nullahs overflowed washing away culverts and small bridges. The city's drainage system seemed non-functional as gushing water on the roads swept away scores of cars, motorcycles, and scooters, ripped out paver blocks from pavements and eroded the road surface in several places.

Mapping of flash floods in Fig. 2 clearly shows that majority of flash flood locations are away from Rivers. Light orange color shows Pune city and the green areas are surrounding villages.

As per the site survey, Dr Gabale has identified 66 flash flood locations in Pune city. Most of the locations are in major chowks and near to crowded spaces. No proper sewage system and waste being pumped into water bodies, increased runoff owing to cement and concrete roads, Diversion of streams, Deposition of construction debris in streams are the reason behind the flash floods in urban area.

Pluvial, or surface water flood, is caused when heavy rainfall creates a flooding in an urban settlement. This is not related to an overflowing river. This typically happens when the urban area is saucer shaped. Rainwater saturates an urban drainage system and water flows out into streets.

This is the situation which Pune city was put into. The important lesson here was that pluvial flooding was not just on the riverbanks, but was scattered across the city

Causes of Urban Flooding

As described earlier, in urban areas the drainage pattern of rivers and its feeder streams get affected to large extent due to development and encroachment. This is the main reason for flooding in urban areas. Few other factors also contribute significantly to this man-made catastrophe. Major factors are as follows :

1. Flash floods occurring due to topographical changes in source regions of streams and tributaries, flood plains of Mula, Mutha and Pawana and confluences of all rivers.
2. Accumulation of local Rainfall runoffs due to insufficient drainage ways.
3. Lack of sufficient structured and non structured drainage for flood waters
4. Overflowing rivers due to insufficient capacity of rivers to discharge the waters on bank due to encroachments
5. Reduction in aquifer volumes, especially the porous and permeable shallow unconfined aquifers due to foundation excavations
6. Reduction in natural recharge areas owing to building and infrastructure
7. Inadequate and insufficient flood risk assessment and management
8. Natural functioning of rivers and streams in urban areas is affected due to number of reasons. These causative factors exist at various levels in the landscape. Following illustration shows the cross section of river and surrounding city landscape. The flood causing factors exist at each of the landscape feature shown here.

The factors responsible for urban flooding are enlisted and described in detail in Table 1. The factors are listed in a sequence of their occurrence, starting from the river channel towards the hills.

Causes of Flood

Why Pune faces frequent flooding ?

Pune is experiencing frequent episodes of urban flooding every monsoon. These floods happen in a

Table 1

Landscape Feature	Causes of Urban Flooding
River Channel and Riverbed	• Channelization of river • Encroachment / Construction in riverbed • Major infrastructure project in riverbed (Metro) • Redundant structures in riverbed • Unplanned structures – New bridges, Weirs, bunds • Existing debris from old constructions in riverbed • Privately owned structures Samadhis, Kunds (e.g. Someshwar kund on Ramnadi) • Choking off the natural groundwater discharge zones – seeps and springs that bring water from aquifers into the river channel
Riverbank / Riparian zones	• Heavy debris dumping on riverbanks • Development within blue line • Developmental projects along riverbanks • Encroachment along riverbanks (illegal settlements) • Increase in hardscape area
Built infrastructure	• Disturbed feeder stream network • Lack of sufficient structured & unstructured drainage of flood waters • Increase in hardscape area • Underground interventions, especially foundations, basements etc. that lead to loss of valuable shallow aquifer storage
Hills	• Disturbed feeder stream network • Increase in hardscape area • Construction projects • Sub-watersheds of rivers getting affected due to unplanned development, improper EIA studies • Disturbance in natural aquifer recharge areas and springs

relatively short period of time and can inundate an area with several feet of water.

Urban flooding occurs when water builds up due to the incoming flows from outside. Such a build-up is faster than the rate of drainage, infiltration to soil and groundwater and augmentation to storages – both natural and man-made (ponds, tanks, lakes, reservoirs. Also the chain of dams upstream of Pune makes the city vulnerable to flooding from dam releases as well.

Urban floods can cause loss of lives, built capital and are a disturbance in city life. Even though casualties are typically low, the economic damages are high. The 2019 floods in Pune were devastating. They claimed 21 human lives and left many homeless. This flood exposed the impacts of encroaching upon rivers and the network of their streams. Furthermore, dam water released caused high water levels compared to earlier years.

Pune city is more vulnerable to floods due to its saucer shape with hills on the edge, and a chain of dams just a few kilometres from the city, in the upstream region of its rivers. All the causes of flooding are shown in Fig. 3.

Geological framework of Aquifers of Pune city

During a study by ACWADAM, twenty-three units of alternating VABs and CBs were identified in Pune city and its environs, based on the mapping conducted in detail between 450 m above msl to the highest elevation of up to about 980 above msl. The geological map has been produced based on this data and overlaid on the Pune's electoral ward boundary (2017) to provide a micro level perspective of the hydrogeological setting of the city shown in Fig. 4. In simple terms, the shades of pink represent VABs and shades of green represent CBs. The geological map for Pune city was used as a foundation for the more detailed hydrogeological mapping of the aquifers in Pune city.

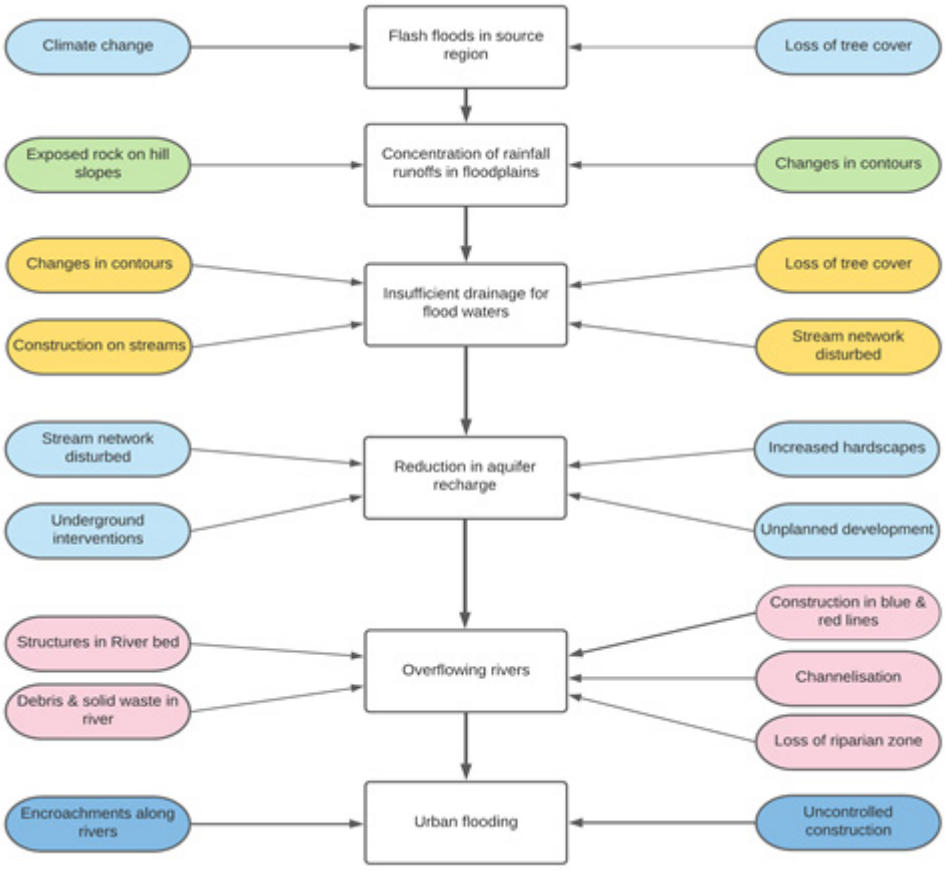


Fig. 3 : Understanding causes: depicted here diagrammatically

Water Level rise and flood alert

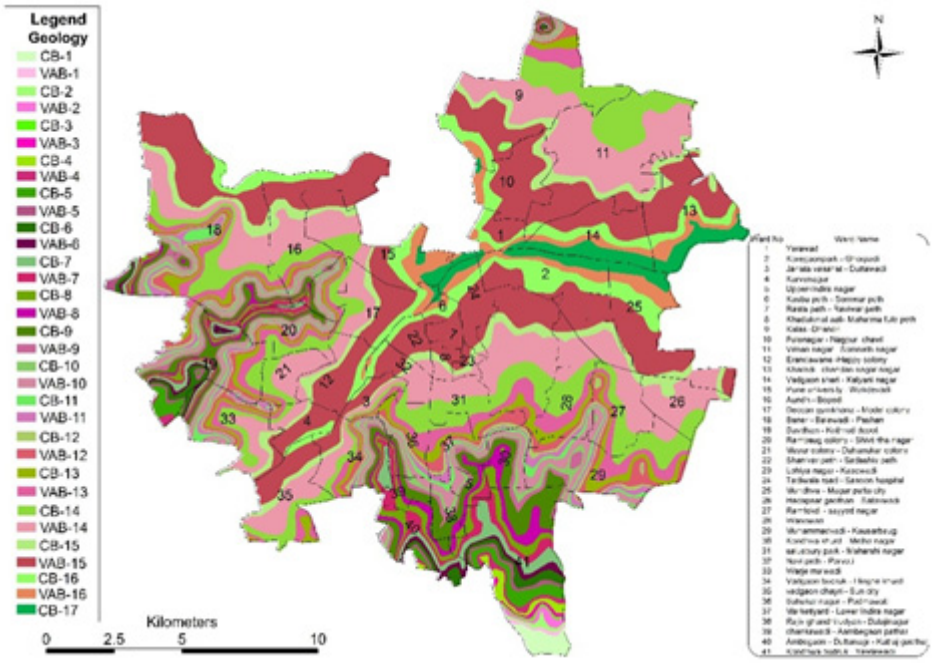


Fig. 4 : Micro level geological map of Pune city Map (ACWADAM)

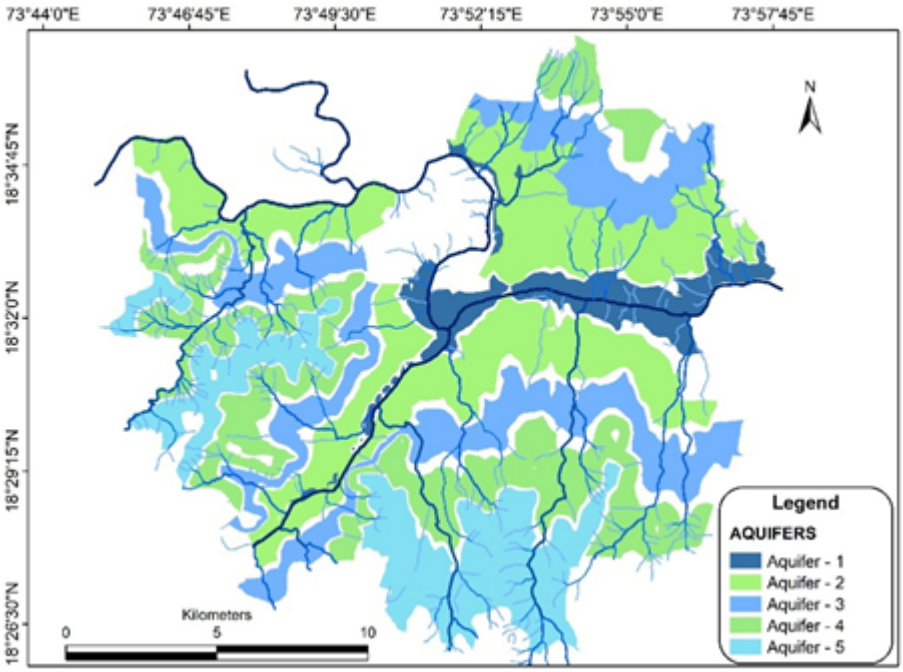


Fig. 5 : Aquifer disposition map of Pune city (Map: ACWADAM)

An aquifer map shown in Fig. 5 represents the disposition of the shallow unconfined (phreatic) aquifers for Pune city. Pune city has five aquifers - Aquifer 1, Aquifer 2, Aquifer 3, Aquifer 4, and Aquifer 5 - in increasing order of their elevations (above msl) where they are exposed at the surface. These five aquifers are generally about 10 to 20 m thick.

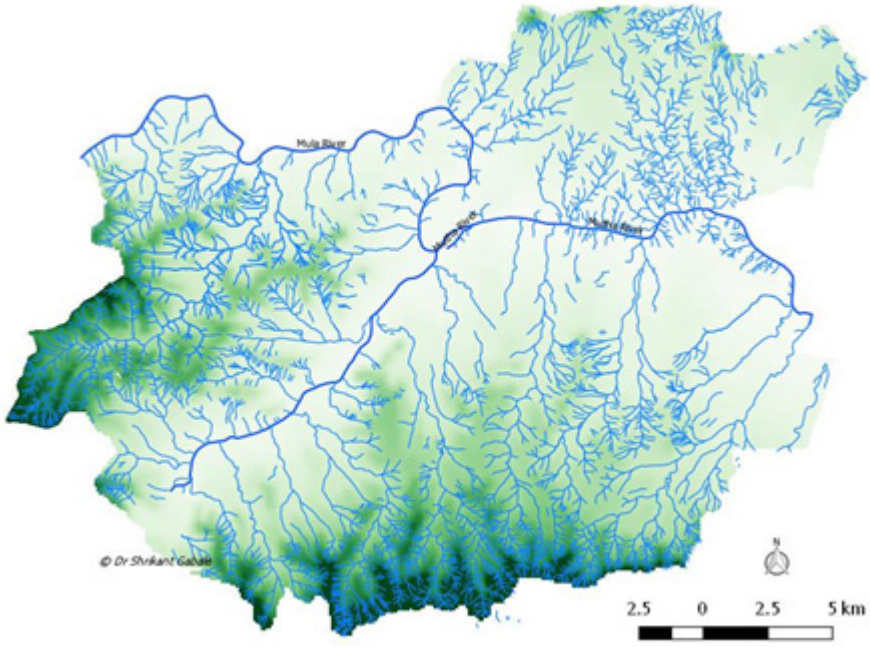
To mitigate and control the urban flooding situation in the near future, it is imperative to understand the aquifer wise natural recharge areas and their disposition with respect to land use pattern and the geomorphic zones that overlie these aquifers, in order to device any flood mitigation strategy.

To overcome the flooding situation and to restore the natural setup of streams and Aquifers, groundwater recharge is an essential component, which can be achieved by application of ''Managed aquifer recharge'' (MAR). Based on the exposed locations of the tops of the aquifers in Pune city and based on the groundwater level data for two seasons, were further used to sharpen the location of the zones of natural groundwater recharge along the contours of the land where the tops of the main aquifers were mapped. The recharge zones also coincide with the watershed map of the city. In order to illustrate the correlation between recharge areas and Pune's watersheds a map, an overlay of the key zones where natural recharge conditions exist is provided below, indicating those areas that must constitute the priority zones for recharge and recharge area protection in Pune city.

Physical Setting of Pune

Pune is situated on the Deccan plateau and lies on the leeward side of the Western Ghats with an average altitude of 560 m from the mean sea level. It is located at the confluence of the Mula and Mutha rivers and lies between latitudes 18º25′ N and 18º37′ N and longitudes 73º44′ E and 73º57′ E. River Mutha passes through the city and has an asymmetrical valley. Pavna and Indrayani traverse the North-Western outskirts of the urban area. The highest point in the city is Vetal Hill (800m above mean sea level-(MSL)) whereas the highest point just outside the urban area is the Sinhagad Fort (1300 m above MSL). The general drainage pattern formed in this area is of dendritic type.

Ramnadi and Devnadi are tributaries of Mula river meeting her at right bank in Baner area. Pawana river, travelling through Pimpri Chinchwad Municipal Corporation area merges into Mula river from the left bank in Dapodi. The Mula and Mutha rivers further merge with each other near College of Engineering, Pune forming Mula-Mutha river, which further meets Bhima river at Ranjangaon Saandas in Shirur Tehsil. Bhima river meets Krishna river in the state of Karnataka, which ultimately drains into Bay of Bengal in Andhra Pradesh.



Map showing rivers in Pune city

The Mula and Mutha rivers have dams in their source regions, upstream of Pune city. Mutha River has four dams Khadakwasala, Panshet, Warasgaon and Temghar. Water is discharged into river / supplied to Pune city and rural areas through Khadakwasla dam. Mulshi Dam is on the Mula river which is a hydro power dam by Tata's. Pawana dam spans the Pawana river. These dams play a significant role in the water levels in these rivers. Each river also has its sub-watershed within city, with network of feeder streams.

Pune city falls within flood plain area of rivers, the very basis of establishment of Pune city. In the flood-plain region the rivers deposit fertile silt and sediments along its banks. These fertile banks are ideal for agriculture and thus attract a settlement.

Changes in the environment are the unavoidable consequences of development. The expansions of Pune city over the years and rising construction activities have altered the topography, drainage, and geomorphic elements of the region. Various negative impacts on the physical environment such as loss of agricultural land, surface and groundwater depletion, changes in geomorphic features, flooding, and others, have increased as the city expanded.

Pune Floods and City Development

Pune's geographic conditions are conducive for development and expansion and this has led to conversion of agricultural lands to settlements along rivers and streams. Soon, settlements started creeping up along the slope of hills, and the changed landscape has disturbed the natural flow of streams. This has disturbed Pune's water table and ecology around it causing streams to disappear over the period. Debris dumping has caused choking of stream and river bases, which prevents percolation of water and broke stream links which triggered water logging. This has led to flash floods in the rainy season.

Due to building and construction, streams connecting with Mula and Mutha rivers in central Pune are getting blocked or choked causing hazardous conditions in many areas. Increase in impermeable surfaces is one of the many human fabrications that dislodge hydrological processes. The result of this barrier is increased runoff, higher stream channel velocities and greater flooding.

Healthy urban streams have been recognized as a fundamental prerequisite to achieve sustainable management of our cities and fulfilling our imperative to maintain healthy aquatic ecosystems for future generations (United Nations General Assembly 1987). There are several excellent summaries on the effects of urbanization on stream health (Walsh et al. 2005). Urbanization alters river ecology in and downstream of cities, harming aquatic systems and prompting efforts to protect, rehabilitate, and even fully restore urban streams. Yet these efforts seldom succeed, mostly because of narrowly prescriptive solutions that do not take advantage of interdisciplinary knowledge in the physical, biological, and social sciences or because they do not treat the full range of urban change in streams (Karr and Rossano 2001).

Drainage Network in Pune

Dendritic or tree shaped drainage pattern is observed in Pune and surrounding area. Being a hilly region, the network of tributaries of various orders and magnitudes, which shows a good drainage density. At city level, a common problem is observed that the management of a single, natural unit such as rivers or streams basins, is divided between several administrative divisions, resulting in dispersion of efforts, and perhaps conflict.

Pune city is settled along two major drainage basins - the Mula and Mutha river. Fig. 6 shows a detailed morphometric analysis of Mula and Mutha river basins by dividing them in major and minor sub basins was carried out by Dr Shrikant Gabale. The map below shows a clear drainage density network of streams from 1st order to 5th order and meeting the rivers. The density of streams clearly indicates the intricate drainage network at the same time.

The Mula and Mutha basins have 2246 first order, 483 second order, 128 third order, 28 fourth order and 6 fifth order streams. These two major basins are divided in to six sub basins -Nandoshi, Ramnadi, Ambil Odha, Bhairoba Nala, Wadki Nala and Wagholi. These sub-watershed basins cover about 35% of total area of Pune. These watershed areas are having rapid urbanization since year 1980 till date.

Sub watersheds / sub basin areas of Pune:

The development of Pune city can be observed within these sub basin areas. As per the topographical characteristics of Pune city, concentration of first order streams in southern area is more than other area. Around four major watersheds are occupied in southern zone. Nandoshi, Ambil Odha, Bhairoba Nala and Wadki Nala are major watersheds with fifth order streams.

The North-West area is covered with hilly terrain having major hillocks presently situated in this area. Vetal hill range from Kothrud is the water divide for Mula and Mutha rivers. Streams flowing from Aundh,

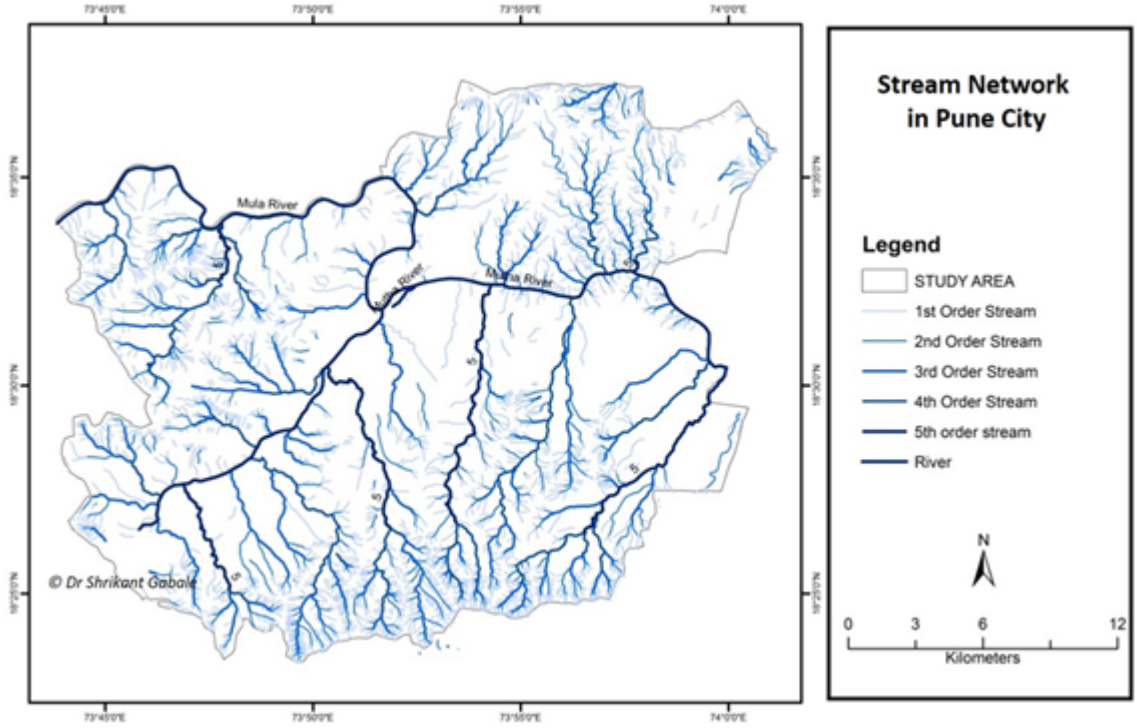


Fig. 6 : (Map: Dr. Shrikant Gabale) showing drainage density of Rivers and Stream Network in Pune City

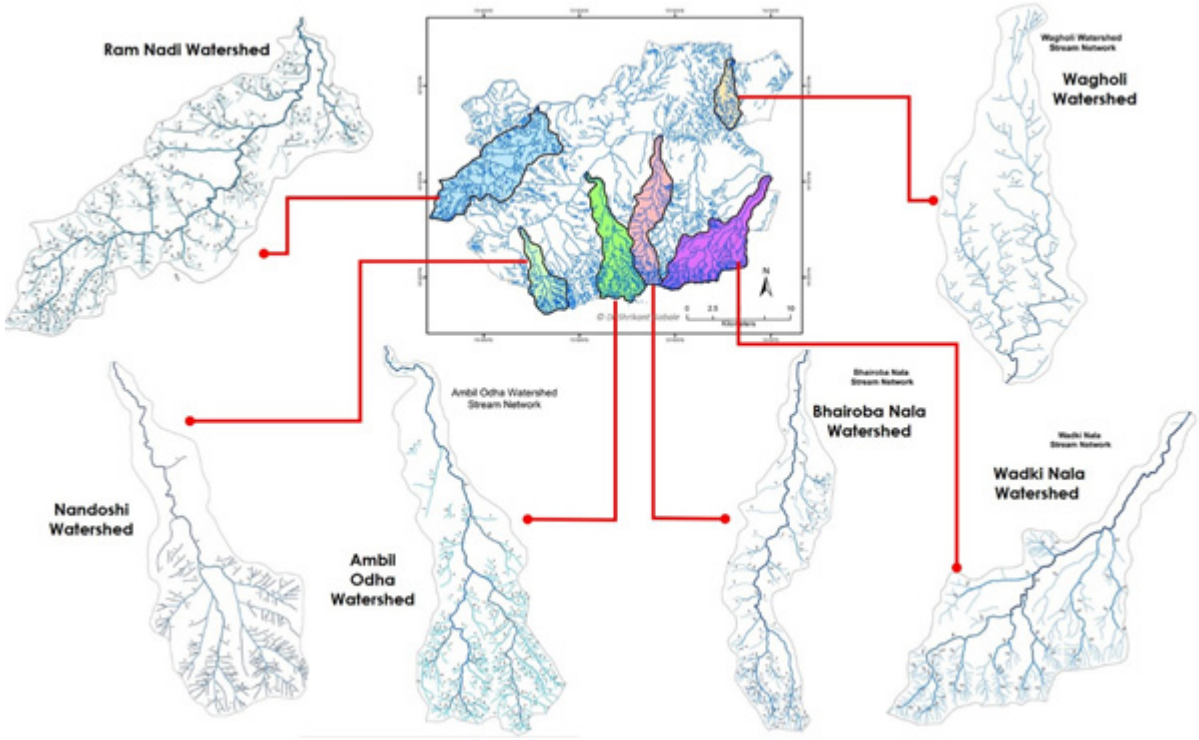


Fig. 7 : Major Sub-Watersheds in Pune (Map: Dr. Shrikant Gabale)

Baner, Sus and Mahalunge area are the part of Mula river system. Ram Nadi plays important role in this area, which covers major part of the area.

The northern area, especially Dhayari, Viashrantwadi, Lohgaon and Wagholi follow dendritic pattern of stream network. Concentrations of first order streams are highest in this area because of change in geological flow. This area is in Dighi hill range having uneven topography i.e. flat and small hillocks. Most of the streams in this region are non-perennial.

The central part is relatively flat and can be identify as river valley of Mutha and Mula Rivers. This area is occupied by 4th and 5th order streams. Refer to Fig. 7.

Geology of Pune

The geology of the Pune region is dominated by a sequence of basalt (lava) flows. The lavas disposed are horizontal "flows" giving rise to a 'trappean' landscape of a step-like morphology called 'traps'. Each lava flow varies in thickness from 10s to 100s of meters. These basalts were formed from lava erupted on the surface, some 65 million years ago. The lava solidified, weathered, and was fractured subsequently. Based on their nature and geometry, basalts are broadly classified into two major hydrogeological types, namely, the vesicular variety (VAB) which has numerous voids and pores along with horizontal sheet joints and the other is the compact variety (CB) which is massive and compact with fewer openings that are largely vertical in nature. Each lava flow can be divided into such units and sub-units to make a fundamental hydro geological differentiation, even at scales of river basins.

Geomorphic Zones of Pune city and its surrounding Areas

Based on geological setup and geomorphology of the region, the Pune City area shows two major geomorphic units, as shown in Fig. 8 :

1. Upper Diagonal region (River plain Area)
2. Lower Diagonal region (Upland Area)

Here, the Upper Diagonal region shows the river plane province of Mula-Mutha River. The Dighi hills act as a water divide between Mula and Indrayani River, which lies to North of Dighi Hills. Confluence of Mula and Mutha River is in the central part of Pune, which flow from West and South-West direction, respectively.

Scarp zone is a cliff or steep slope. A spur is a long, gently-sloping 'tongue' of ground that runs down from a hill to lower ground. A spur is often formed by two roughly parallel streams cutting draws down the side

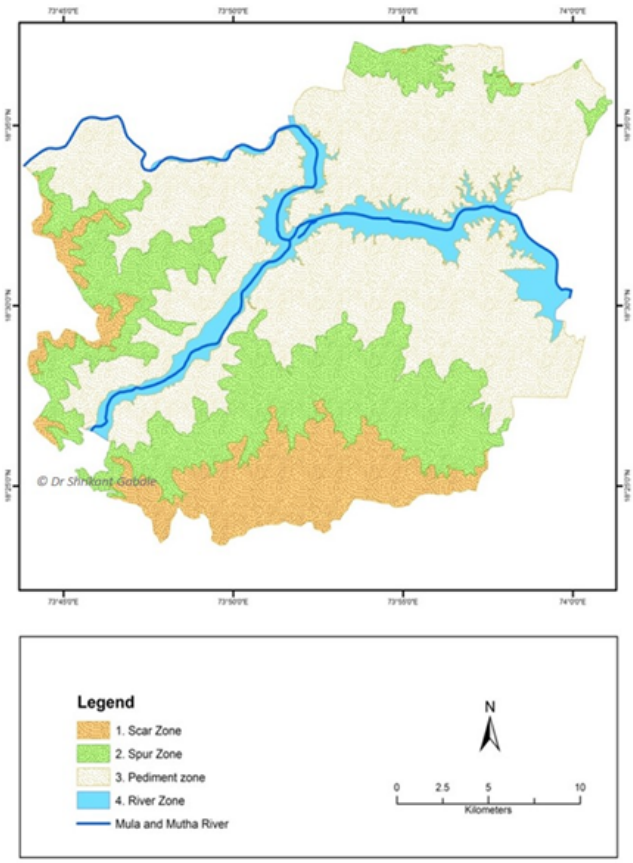


Fig. 8 : Geomorphic map of Pune City (Dr. Shrikant Gabale)

of a ridge.

The spur zone is followed by the pediment zone which covers the largest portion in the Pune city, which is 279.25 sq. km. This pediment zone is nothing but a river depositional zone and represents the valley. This is dominated by Mutha River drainage basin area to the eastern side. Pediment zone of Mula River lies to its right bank and the North Western side. The pediment area widens towards east as both the rivers reach their pre-mature stage. Their early mature stage denotes minimum pediment area. The dense population is settled on this pediment zone of Mutha river.

An area which comes under a maximum discharge of river to its normal position afterwards is considered as a riverbank. This is the flood plain region of the river. In Pune, river zone covers 46.76 sq. km. As both rivers are flowing in their matured stage, this region is mainly dominated by river's depositional activity. The rivers deposits alluvial materials near confluence, increasing channel widths of both river channels. Near the confluence, a depositional island 'Naik bait' is formed due to heavy sediment depositions over the

period. This natural island is also occupied by human settlement.

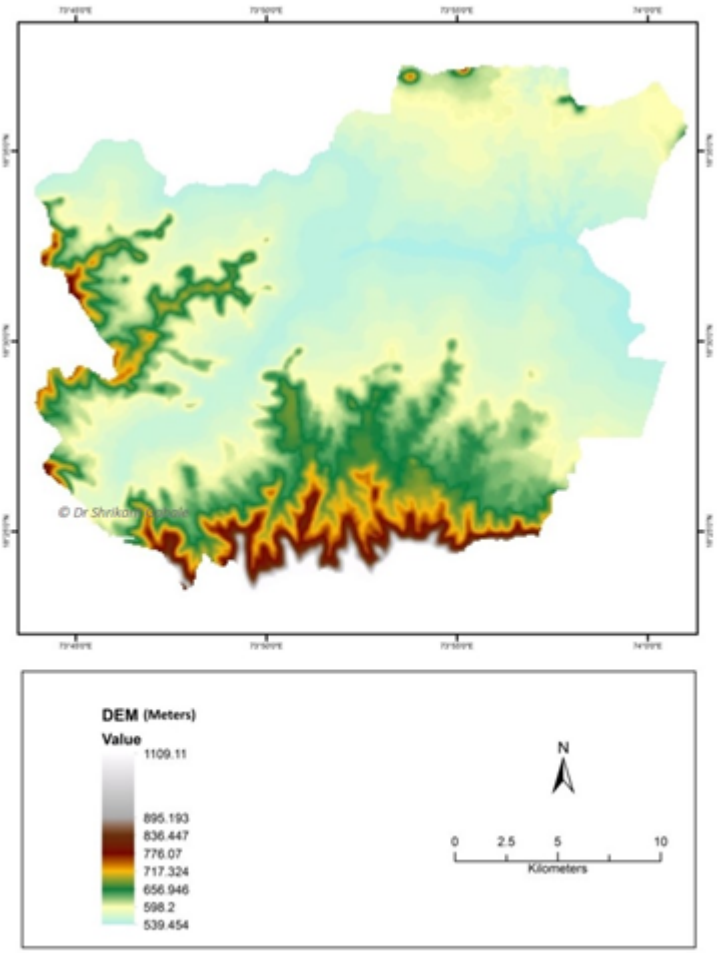
Fig. 9 shows map of administrative wards situated at different elevation levels in Pune city.

Changes in Land Use and Land Cover

The study conducted by Dr. Shrikant Gabale, in Pune and its surrounding areas indicates that multi-temporal remote sensing images i.e. Landsat images are useful to detect the changes in land cover quickly and accurately. The study reveals that the major land cover categories in Pune city in which changes over the years were observed are water bodies, vegetation, and settlement area. Overview of changes in Land Cover over the years from 1991 to 2015 is as follow :

Pune 1991 : The results of classification suggest that area under Water bodies accounts to 1.70%, area under Agriculture is 4.65%, Vegetation is 25.76%, Settlements is 29.07% and Open/Barren Land is 38.82% of the total area and thus this total area is divided in above five components or areas. The image shows natural, physical, and human intervention in the study area. Vegetation, Open/Barren Land and Water bodies together occupy 66.28% of the total area. Human settlements and agriculture land occupy 33.72% area. These percentages suggest that the impact of human activities or human interference on nature or physical features were comparatively less during these years.

Pune 2015 : Area under water bodies accounts to 0.92%, Agriculture 1.08%, Vegetation 14.22%, Settlements 49.30%, and Open/Barren land occupies 34.48 %. The natural features like Vegetation, Open/Barren Land and water bodies occupy 49.62% of the total area and human settlements and agricultural land occupy 50.38 % of the total area. Comparing it to physical aspects of the study area in year 2015, an unambiguous difference is observed in area under water bodies (422.33 Ha.) indicating heavy development along them,



Elevation Class (Mtr.)	Color	Wards (Administrative Division)	Villages
900-1109		-	Kolewadi, Yewalewadi, Bhalarewadi,
770-900		-	Holkarwadi, Yewalewadi, Bhalarewadi, Kolewadi, Handewadi, Kopare, Bavdhan
710-770		Kondhwe, Kopare, Aundh, Karve Rd	Handewadi, Holkarwadi, Wadachiwadi UrukiDevachi, Bavdhan Mangalewadi, Yewalewadi Nandedhi, Sus
590-710		Bibwewadi, Dhanakawadi,Ambegaon Bk and Kh. Dhayari, Kirkatwadi, Kondhwe, Warje, Shivane, Bavdhan, Aundh, Karve Rd, Sahakar Nagar, Hadapsar	Handewadi, Holkarwadi, Wadachiwadi, Undri, Pisoli UrukiDevachi
539-590		Tilak Road,Sahakar Nagar,Vishrambaug Wada,Pune Cantonment, Ghole Road, Dhole Patil Road, BhavaniPeth, WarjeKarve Nagar, Karve Rd ,Mhalunge,Aundh, Mundhwa, Yerwada, Sangamwadi, Khadki Cant, wagholi, Lohegaon	Khadakwasla, Nanded, UrukiDevachi

Fig. 9 : Digital Elevation Model (DEM) of Pune City (Map: Dr. Shrikant Gabale)

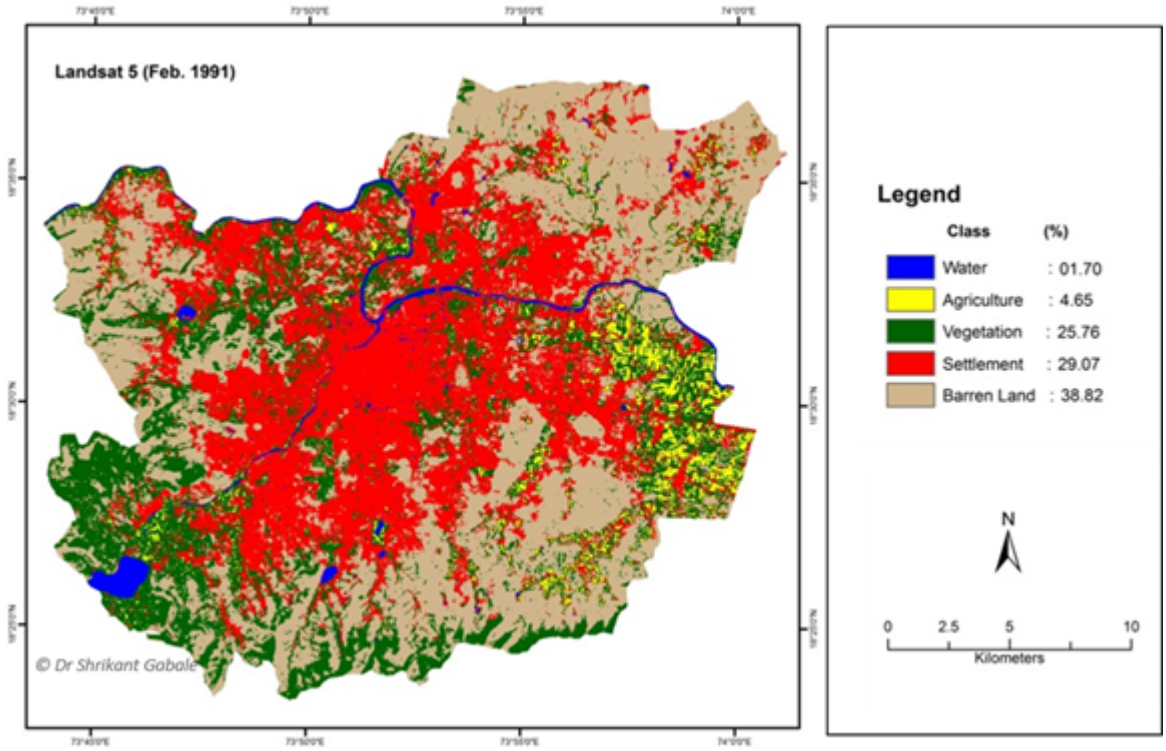


Fig. 10.1

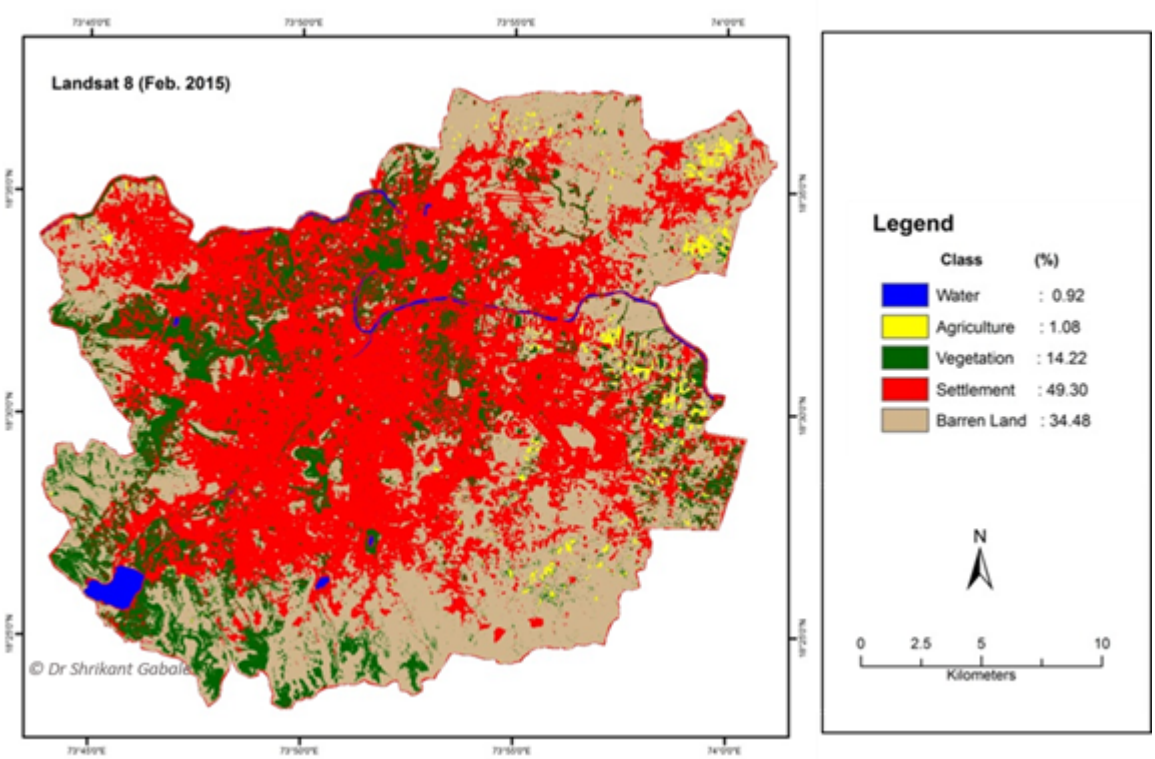


Fig. 10.2

Table 2

Sr. No.	Class / Land Cover Type	1991	2015	Difference from year 1991 to 2015		
		(%)	(%)	(%)	(Ha.)	(Sq.km.)
1	Water bodies	1.70	0.92	0.78	422.33	4.22
2	Agricultural Land	4.65	1.08	3.57	1932.97	19.32
3	Vegetation Cover	25.76	14.22	11.54	6248.33	62.48
4	Settlement area	29.07	49.30	20.23	10953.53	109.53
5	Open / Barren Land	38.82	34.48	4.34	2349.89	23.49

Source: Dr Shrikant Gabale Report

and a swift increase in area under settlement (10957.87 Ha.) is observed endangering vegetation cover and conversion of Open/Barren land in and around the city. Hence, heavy urbanization is reason for depletion of good fertile land in Peri-Urban area, heavy development along water bodies and vanishing of non-existing streams. Refer Table 2.

Ram Nadi

The History and Mythology

Ramnadi, is an ancient river flowing through Pune District of Maharashtra, India. It is a tributary of the Mula river which is part of the Bhima river basin and the larger Krishna river basin which discharges into the Bay of Bengal.

Ramnadi originates in the Jarsheshwar Hills and has a catchment area in Angrewadi, Warpewadi, Khatpewadi and Pansare-Vasti regions. The water from these areas converges at the Rameshwar temple in Bhukum, where the origin of the Ramnadi is traditionally placed. The river descends in steps through Khatpewadi Lake, Bhukum, Bhugaon Lake, Bavdhan Budruk, Bavdhan Khurd, Sutarwadi, Pashan Lake and on towards the confluence with the Mula river in Baner. All these man made lakes are shown in Fig. 11, depicting cross section of the area.

The villagers in the source region believe that the central characters of the Ramayana Epic. Lord Ram, Sita and Laxman had stayed at the Jarsheshwar Hill which was a part of Dandakaranya, the ancient forest. The hill is known as Sitecha Dongar which means lord Sita's mountain. A series of temples and lakes along the river stand in testimony of rich cultural life of the civilization in the Ramnadi basin. The Ramnadi descends in uniquesteepsteps and terraces, from the Jareshwar Temple, and along the Rameshwar Temple (Bhukum), the Vitthal-Rakhumai Temple (Bhugaon), Wakeshwar Temple (Bavdhan) and Someshwar Temple (Baner). The Someshwar Temple was built sometime during the rule of Chatrapati Shivaji Maharaj. His mother, Jijabai used to bring the young Shivaji here. The Someshwar temple complex has a Kund, which is a constructed water tank. This kund allows water from springs to accumulate and this water is further released through gates built in those

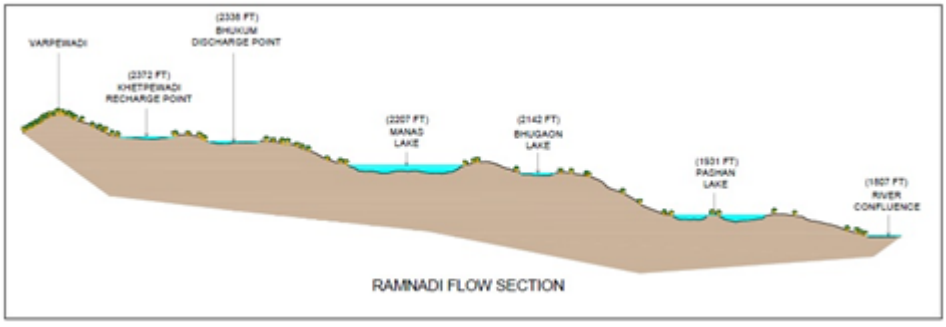


Fig. 11

times. As the Ramnadi descends, the Sita Doh, or Sita's lake forms at Bhukum. This too is an ancient water body. The Khatpewadi Lake was created by walling a stream of the Ramnadi, during the 1972 drought. Further down, the Ramnadi is walled and the collected water is called the Pashan Lake. This lake was created in the British Raj to supply domestic water to the Governor's house, which is today the Savitribai Phule Pune University.

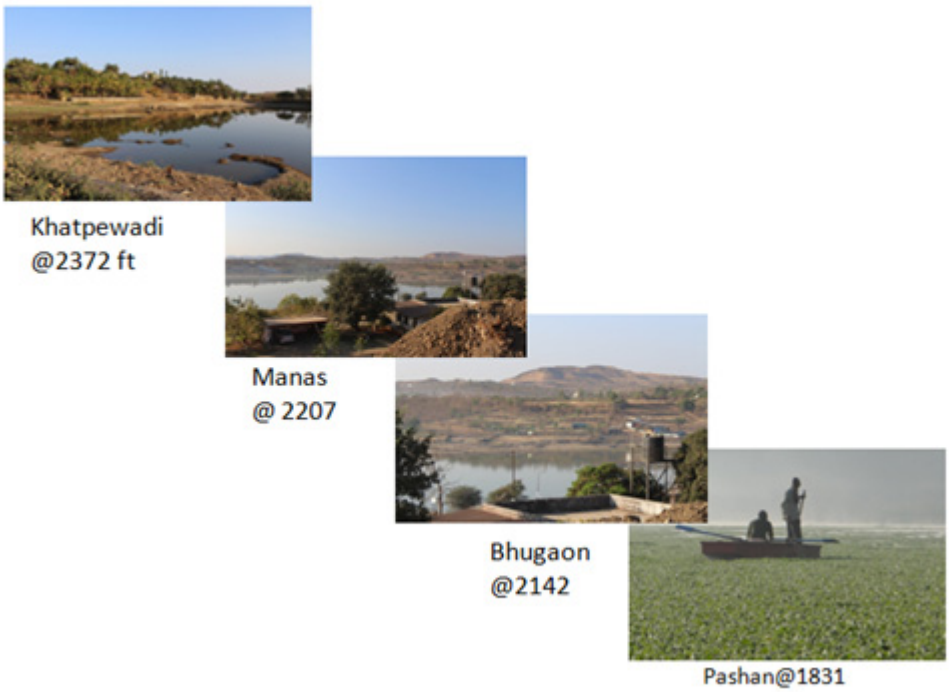
All the lakes are manmade lakes. Until few years ago agriculture was main occupation along banks of Ramnadi. But water demands were met by these lakes. They also support the Ground water recharge and absorb floods.

Ramnadi is an important tributary of Mula river. The river flows in a north-easterly direction and finally confluences Mula river near Baner. The total watershed area is about 63 km2. The highest point is situated near Bhukum (800 m above MSL). The lowest point is situated near Baner (560 m above MSL).

The watershed comprises vesicular amygdaloidal basalt 1 (VAB -1) is exposed at higher elevation in Mukai wadi area, while VAB - 5 is exposed at lower elevations in Baner area. Pashan lake is located on VAB-4. Bhugaon minor irrigation tank and Bhukum percolation tank are located on CB-2 and Mukai wadi tank is at the contact of VAB-1 and CB-2. The topography of the area is rugged and undulating, in the upper part of the basin and even in the valley portions. However, after Someshwarwadi, the valley tends to become comparatively flatter.

ACWADAM have mapped 5 aquifers in Ramnadi watershed. Please refer to Fig. 12. The typical lithological setup has been identified in the Ramnadi watershed involving amygdaloidal basalt capped by red tuffaceous layers and underlain by compact basalt. Aquifer 1 is the thickest aquifer in the watershed and compact basalt constitute major portion in this aquifer, while amygdaloidal basalt is approximately 13 m in thickness. It is exposed in upper reaches of the watershed and is largely unconfined in nature. Aquifers 2,3,4 are intermediate aquifers. Aquifer 2, 3 exposed at Bhukum and Bhugaon area are unconfined in nature. While borewells in this area tap aquifer-4 as confined aquifer but the same lithologies are exposed at Bavdhan and Pashan, where it is an unconfined aquifer. Aquifer 5 acts as unconfined aquifer at Pashan and Baner area, while it is confined at Bavdhan and at higher elevation in Pashan as shown in figure below.

In the watershed, thick vegetation cover has been observed along entire stretch and especially along the Ramnadi river course. Less disturbed ecosystem in upper and middle reaches than lower reaches because of human interventions to the nature. The proliferation



Sequence of photos of man made lakes in Ramnadi

of urbanization in the lower reaches and recently even in its upper reaches has surely affected both the aquifer storage capacities and recharge. Moreover, groundwater abstraction increased due to (urbanization). With reduction in natural recharge and the loss of aquifer material has implied a gap between demand and availability of groundwater resources. While studies on groundwater quality are in progress, quality of groundwater based on random samples seems to have deteriorated, because of many factors.

Changing precipitation patterns and increased intensity of rainfall along with the aforementioned factors is likely to result in a higher probability of urban flooding, particularly in the downstream portions of the Ramnadi watershed.

For two decades, Ram Nadi has been in spotlight due to urban encroachment. Areas such as Bhukum to Baner, having new constructions, are facing flash floods. Despite that, plotting and construction activities at the source of Ram Nadi are increasing day by day. Half of Bhukum has hilly terrain, which lies offshoot of Sahyadri range. From Manas Lake to Bhugaon Village, this river flows like a minor stream, with sewage and construction debris being deposited in the stream along its way.

In the last 5 to 6 years, construction activities have increased near Paud-Pirangut area, so its impact is seen on total landscape of concerned area. It is observed that, flash flooding is activated mainly in rainy season because of dumping construction debris and sewage deposition, ultimately blocking the natural flow of stream.

The second part of Ram Nadi flows from Bavdhan to Pashan area. Due to unplanned construction activities, 20% of total streams of this watershed have non-exist. At both sides of Bavdhan road, near Chandani Chowk, around 7 first order and 3 second order streams have vanished. Sagar Cooperative Society, Vinyan nagar society and Shinde nagar area are located on streams, which have disappeared. The eastern sides of Bavdhan, foothills are excavated (300 slope) and totally occupied by commercial and residential buildings. Pashan Lake, having historical importance has been destroyed due to dumping of sewage and construction debris.

Pashan - Sus road is constructed in east- west direction on north- south Pashan hill cutting the hill against slope and residential development from State Bank Nagar to Pashan Lake which covers half the hills are the main cause of obstructing the natural flow of water.

Ram Nadi has no proper flood line demarcation done till today. Reason behind the flash floods, according to residents, is the careless attitude of local government (PMC) towards encroachment into the flood lines of City Rivers / natural streams of Ram Nadi.

The width of the river channel has decreased by illegal construction activity dumping of construction debris near the confluence of Ram Nadi and Mula River. Due to reduction in width of Ram Nadi its channel is burdened by fluctuating volume of water causing harmful conditions for surroundings. Construction of retaining wall along the channel banks by PMC may create problem of flood in monsoon due to

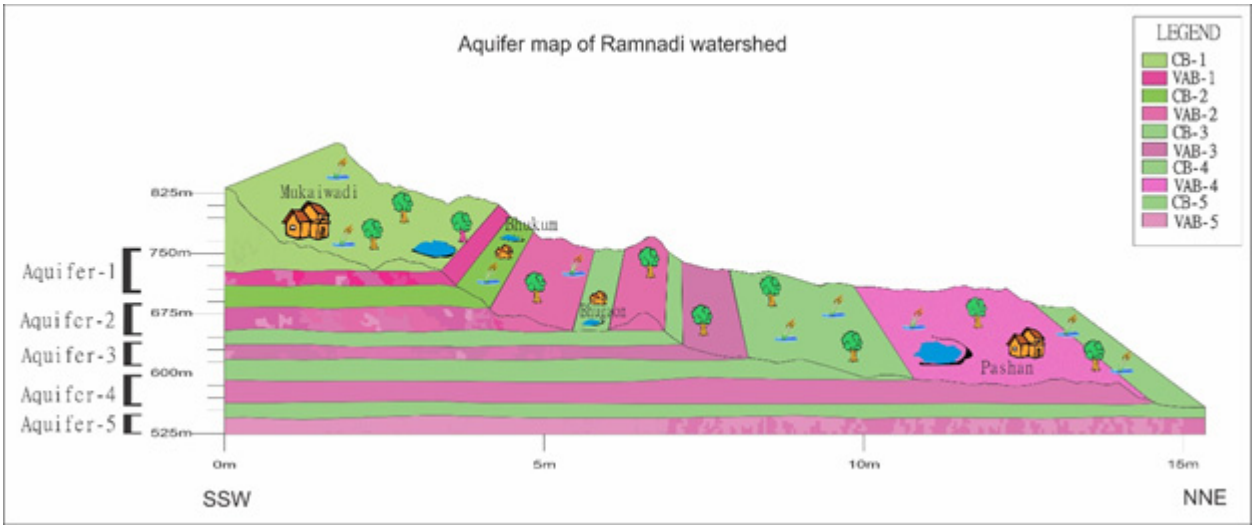


Fig. 12 : Aquifer system of Ramnadi watershed

Retaining Wall in Ram Nadi Channel (front and Back view)

Dumping in Ram Nadi Channel

Construction and Dumping near channel

Construction on Hill slope (Bavdhan Area)

Construction on Stream (Banner - Pashan Road)

Sewage dumping in channel Pashan Gao than

Silt deposition near Pashan Lake

Sewage dumping and unwanted vegetation in channel (Bhugaon)

Construction on stream near Chandani Chowk - Bavdhan

reclamation of land in flood zone by builders or societies. Also, the construction of retaining wall has reduced its width which covers almost 15% of the channel area creating problems like, overflow of sewage which gets mixed with river stream spreading all over causing waterlogs and back wash.

Areas such as Bavdhan, Bhukum, Pirangut and some part of Karve Nagar fall under this watershed study area. Few areas are within Pune city boundary which are covered in the cross sections up to R6 – R10 region. Area between profiles R5 to R7 is more prone to problems as the slope of average 5°-10° (i.e. 1:5) is feasible for construction, and most of the development in recent years has been seen in these parts of study area, causing various environmental problems including flash floods, obstruction to natural flow of streams and also increase in non-existence of many streams. The intensity of development in this area was such that the width of Ram Nadi (River) flowing through the city is literally reduced to 4-5 m i.e. comparatively nothing. Refer to Fig. 13 a, showing cross sections of Ram Nadi at various places.

The longitudinal profile of the river along with the urbanization explains the important relationship with the overall topography of the watershed. Refer to Fig. 13 b, showing longitudinal profile of Ram Nadi It is clearly observed that the source region of the river is having less expansion of the settlements, which is since the source of the river is always at a high altitude and slope. Any river or stream can have overland flow when there is enough water and a particular degree of slope. The longitudinal profile of the river explains the status of the river from the source to its mouth. Ram Nadi has a source elevation of around 875 m from the mean sea level. The graded profile of this river explains that it has been altered by the anthropogenic activities.

Below 629m, there is an abrupt change in the landscape. This is indicated by the degree of slope which gently decreases towards the confluence. The gently sloping land has favoured the human activities in the form of construction of buildings and infrastructure along with its expansion. There is a high density of

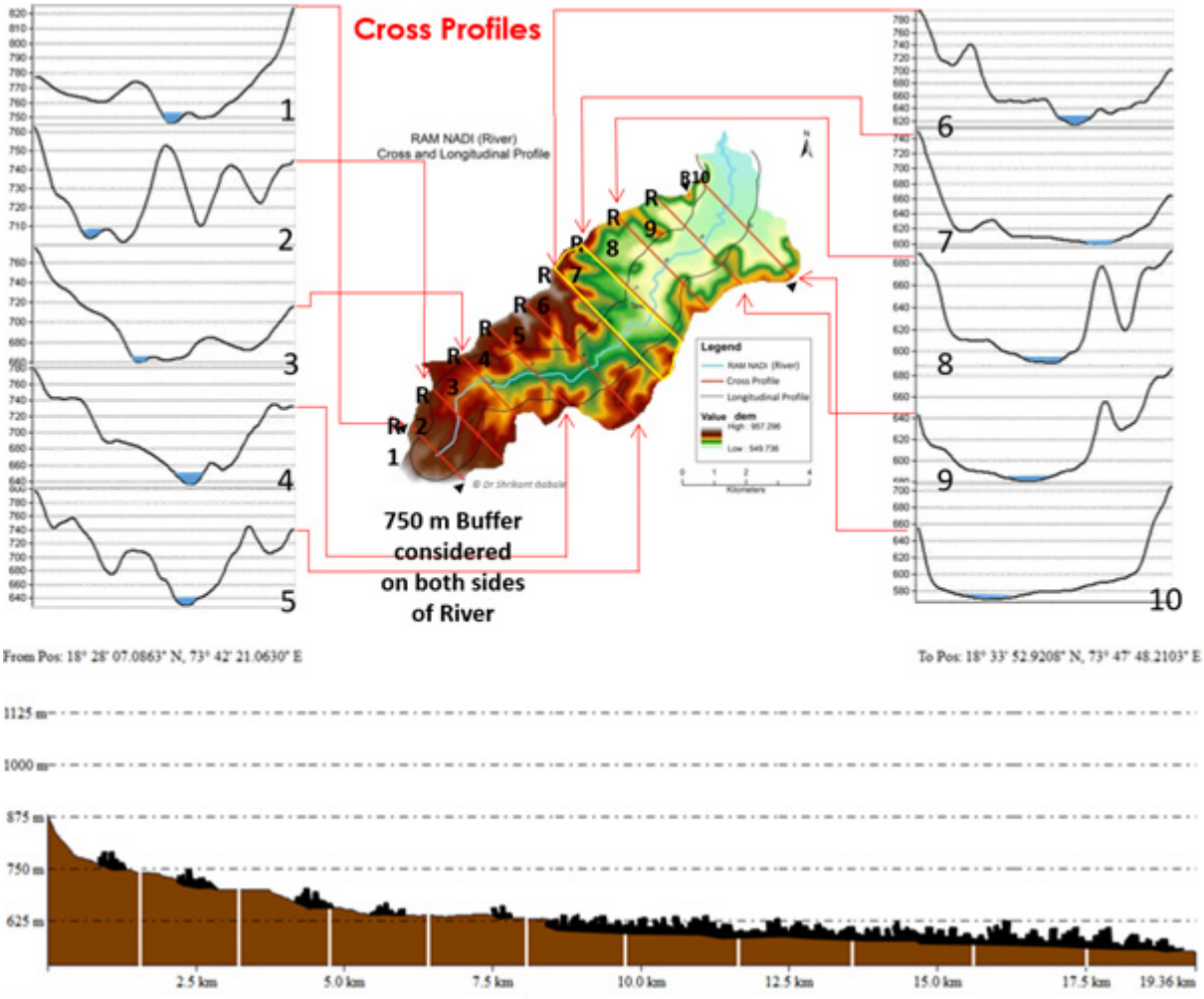


Fig. 13 a and 13 b : Latitudinal Slope / Degree / Gradient analysis done by Profiles and buffer around Ram Nadi

settlement and population growth in this section of topography. It also explains that the human intervention is more in this region.

The longitudinal profile of the river clearly explains that anthropogenic activities have altered the landscape according to human needs. Above 629m (5.75 0), the terraced profile clearly indicates the change in landscape. Below 629m (R5), the profile is gently sloping favouring expansion of human settlements and infrastructure. Most of the settlements in this basin area lie in between 2.610 to 5.750slope. Due to saturation and unavailability of plain land there are some settlements which lie in between 90 to 300 slope regions. Although these slopes are not favourable for settlements, slopes are altered to form settlements and this type of development is increasing observed in early years from confluence to source of rivers.

Ambil Stream

The floods in Ambil odha are consequences of concretisation especially in the recharge zones of the main aquifers and narrowing of stream channels both of which lead to increased overland flow that is beyond the carrying capacity of the narrowed channels, resulting into anthropogenic flash foods. Avoiding such flash floods in the future require an understanding of the relationship between surface water and groundwater interactions and the ecological approaches required for correctable and preventable measures.

At Ambil odha mouth, a pipeline runs right across its width, from Vaikunth, quite close to the stream bed. It is an obstacle to the flow. Garbage gets trapped between stream bed and the pipe, creating a bund like

Table 3 : Ambil Odha stream watershed analysis (Dr. Shrikant Gabale)

Year	1991			2015		
Order	No. of streams	Length (km)	(%)	No. of Non Existing streams (Available streams)	Length (km)	(%)
1st Order	235	67.38	59.10	187	54.587	57.03
2nd Order	40	21.05	18.46	29	15.55	16.25
3rd Order	6	10.41	9.13	5	10.41	10.88
4th Order	2	5.62	4.93	2	5.58	5.83
5th Order	1	9.55	8.38	1	9.59	10.02
	284	**114.01**		**224**	**95.717**	

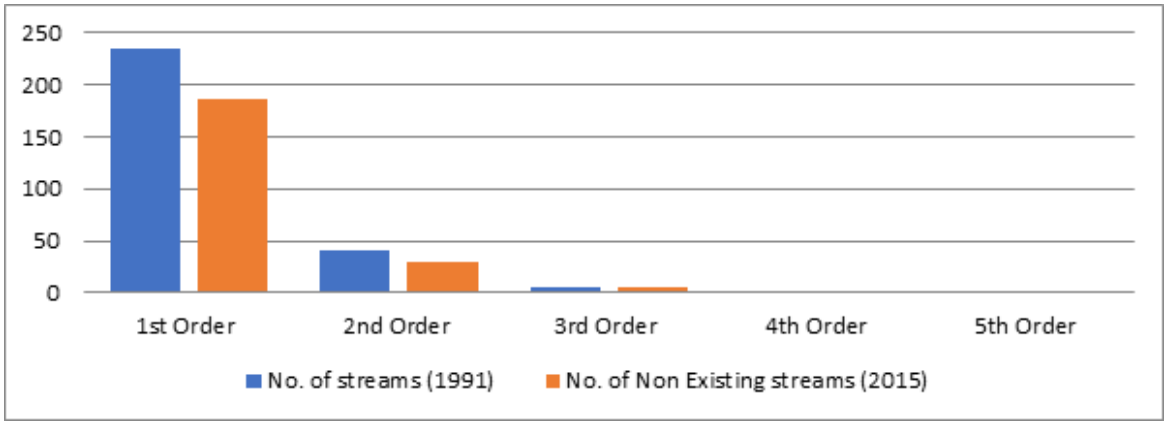


Fig. 14

structure providing further obstruction to the flow. Refer to Fig. 16, showing land-use changes in the Ambil Odha catchment.

Root cause analysis and proposed Solutions

Channelization of rivers, streams and tributaries

Total morphology of Mutha river and most of the Natural drains has been altered. Mutha river is extensively channelized within Pune city. Natural river channel bed has been altered to divert river flow in constructed channel walls. This has resulted in creating drying rest of the channel bed. However, external sewage and other sources of water reaching river bed create stagnant pools along the channels. Such concretized riverbanks alter the natural functioning of river. Natural river channel has its own course carved through millions of years of action. The river flow carries out function of exchange of sediment, silt. There is exchange of surface and sub-surface water between river and riverbank, riverside wetlands.

Ramnadi, Devnadi, Ambil stream are embanked

Devnadi embanked, debris, width reduced

Devnadi floods 2019

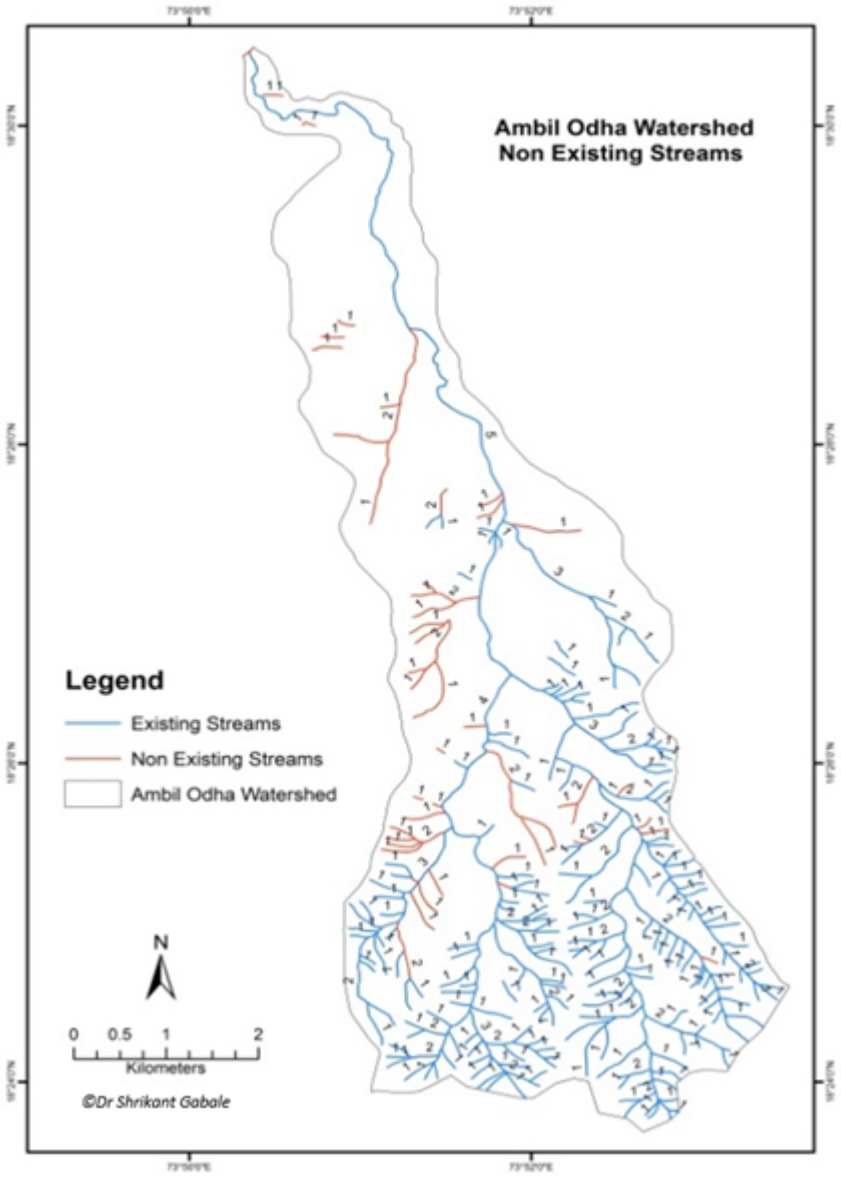


Fig. 15 : Land use-Land Class maps for Ambil Odha watershed (study by Dr. Shrikant Gabale)

heavily reducing the width to more than 50% at some locations. At places the natural drains virtually look like gutters by excessive concretization and channelization.

River flow

Due to concretized bank, the connection of river/ stream with its bank and its area of water spread is broken. This affects various natural habitats created along river, stagnant pools of water are formed in depressions along river, springs meeting river are also affected. In the process, some first order streams are lost. Refer to Fig. 15.

The riverbed area outside the constructed channel becomes easy place for dumping of garbage and debris. All these factors cause obstruction to flood water spread.

What is required?

Removal of concretized banks and restoring the riverbank, riparian zone through ecological measures

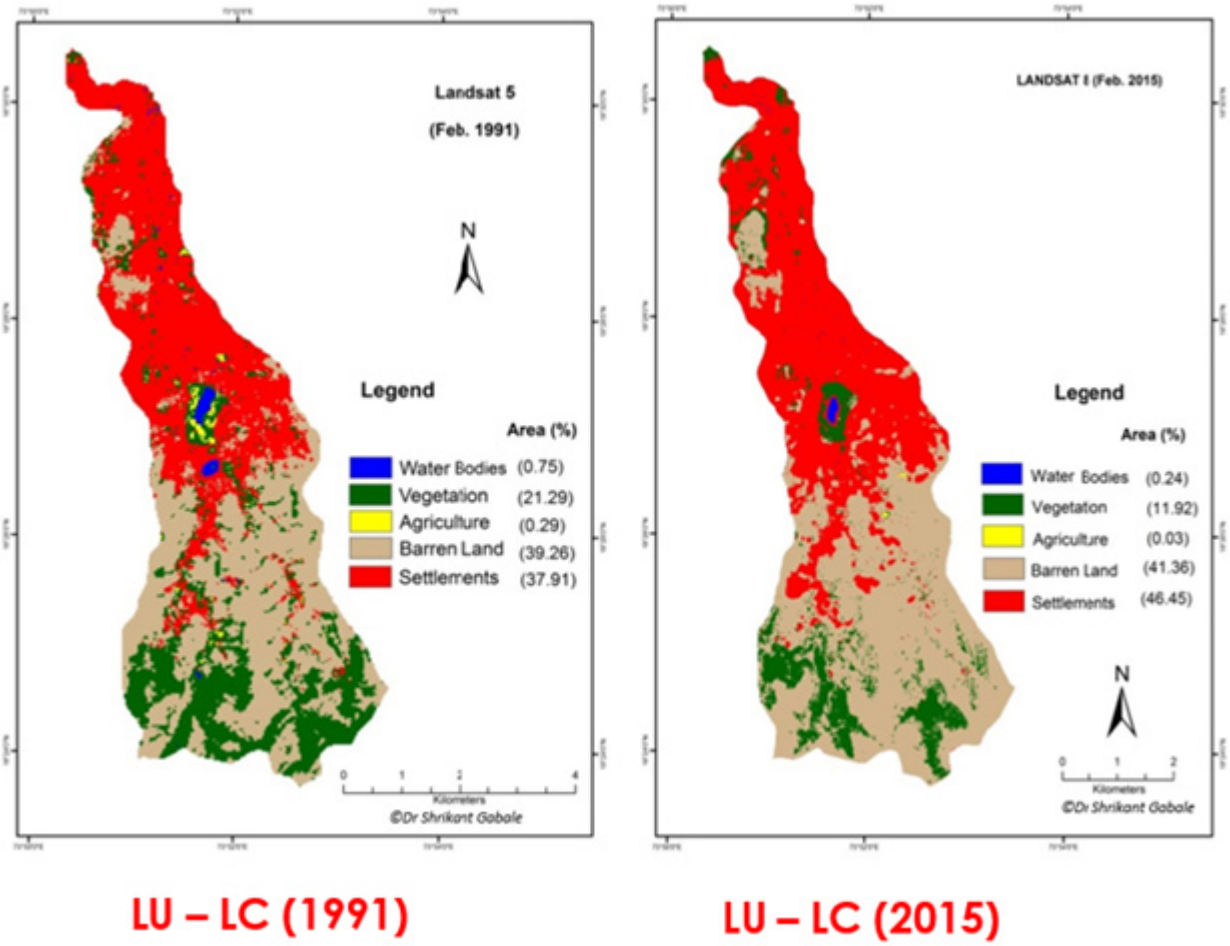


Fig. 16

Ambil Odha mouth

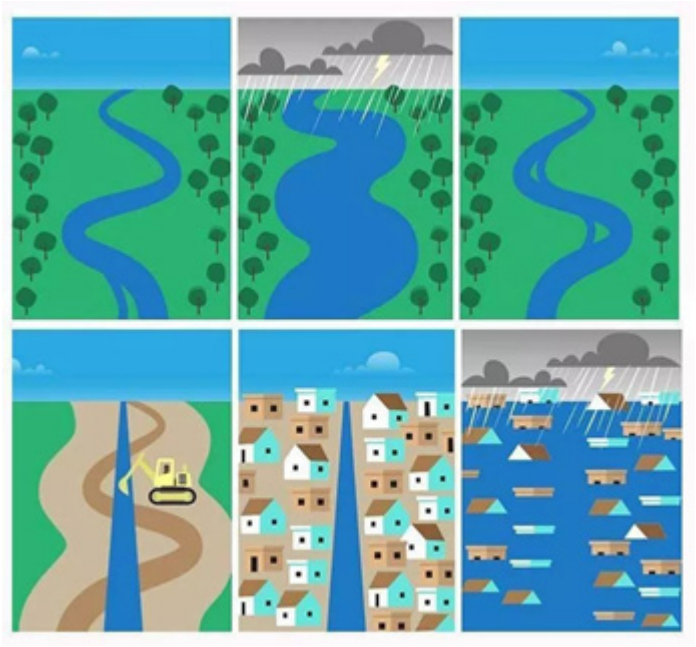


Fig. 17

and protection of springs along riverbed and in source region.

Ambil stream, a natural drain and the important feeder to Mutha river converted to sewage drain

Encroachment / Construction in riverbed

Construction and illegal encroachment are seen within the riverbed. Roads are also planned within riverbed e.g. The 3.5 km road was planned by Pune Municipal Corporation (PMC) from Warje to Vitthalwadi, along Mutha river. This road was inside blue flood line. Petition was filed by Ar. Sarang Yadwadkar against this encroachment. 65% of the road construction was complete by then. National Green Tribunal (NGT) ordered the road to be removed. Supreme Court also continued the order by NGT. Even after orders from NGT to follow flood line rules permissions for construction are obtained. New large residential projects in fast growing suburbs of Baner, Pashan, Bavdhan along Ramnadi pose a great challenge. Fig. 17, clearly shows the effect of loosing natural sinuous channel by constructing straight one becomes flood prone. And new settlements in the flood plains suffering from floods.

What is required?

Removal / relocation of these structures and establishing natural riverbank using ecological measures,

restoring original topology altered by these structures.

Major infrastructure project in riverbed

Government infrastructure projects like Metro, Ring road covers a large portion of riverbank and riverbed. Such heavy concrete structure not only affect river ecosystem but also the groundwater recharge in this zone. Such structures also cause an obstruction to flood water and displace water towards the riverside residential areas.

What is required?

Alternate routes for such transportation projects should be designed with help of ecology and hydrogeology experts.

Structures and Redundant structures in riverbed

In riverbed redundant objects are seen lying like defunct big pipelines, scrap cars etc. Scrap cars are regularly dumped in the riverbed towards the right bank of Mutha, near Chhatrapati Sambhaji Bridge.

Sewage pipeline lying idle in the Mutha riverbed, which is not connected anywhere. It was probably brought for some work and is left as it right in the riverbed.

Sewage chambers, Ganesh Immersion tanks are con-

Redundant structures in Ramnadi, Devnadi and Mula River

structed in the riverbed. All these objects are obstruction to flood water flow.

What is required?

Immediate removal of the defunct objects / structures like K.T.Wiers (which do not serve any purpose) and relocation of other structures.

Debris dumping on riverbanks

Construction debris is heavily dumped along riverbanks. Sometimes it is used for levelling of riverside land for protection of farms / property from flood waters. This hampers the riverbank and its riparian zone, affects ground water recharge, and most importantly obstructs and alters the flow of flood water. It causes breaking of stream links which triggered water logging on sites and flash floods in rainy season.

What is required?

Strict action by Municipal authorities and separate team of 'river watch guards' to be formed for prompt action. Removal of all existing debris along riverbank and restoring the area by ecological measures.

Development within blue line

At many places' development is seen within blue line, some structures are illegal, and some are legally constructed with permission of local authorities. This violation of development plan rules encourages others to follow the same and during flooding such areas are highly at risk and are major obstruction to flood water flow.

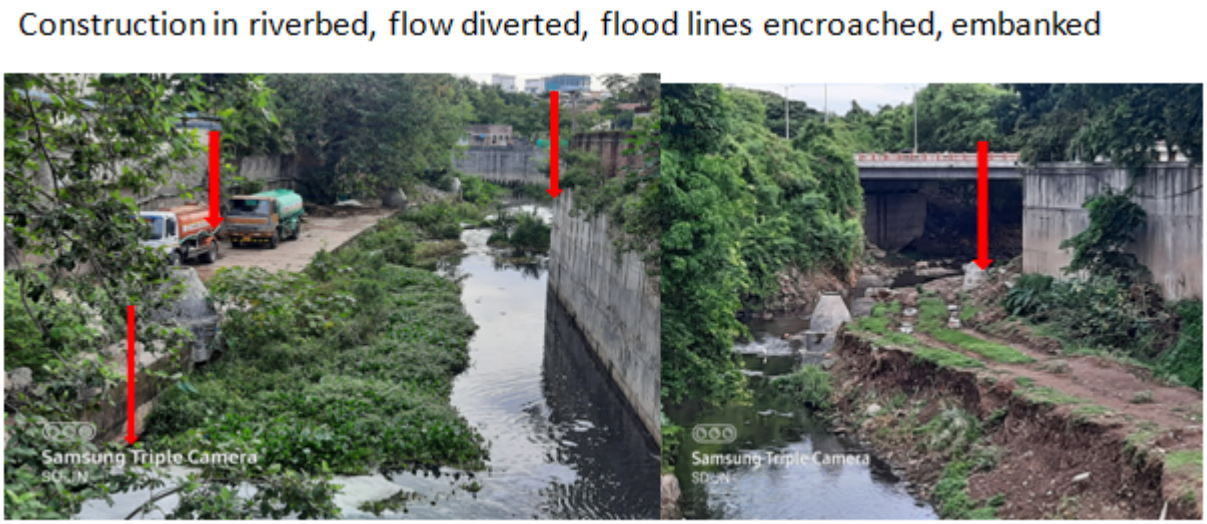
What is required?

Strict action against such violations and removal of the structures. Some policy to be devised for compensation in case construction is prior to establishment of rules.

Developmental projects along riverbanks

Agriculture lands along rivers are rapidly getting converted into non-Agricultural (NA) status and going under developmental projects (building construction and township development). Builder buy huge riverside lands from farmers and do construction activity. In such cases major land use changes all over along river are harmful for river ecosystem functioning. In case of flooding scenario, there is no space left for the flood water to spread, ultimately it causes more harm to human life and to the construction itself. Such large-scale hardscape along river also affects ground water recharge.

Construction in Mula Flood Plain, Diverting Storm drain and reducing stream size, and heavy dumping near Jupiter Hospital



What is required?

Declaring the riverside area as green zone and giving some incentives to farmers for not converting the land to NA status. Green zone area along both the riverbanks to be decided with the help of geology and ecology experts.

Encroachment along riverbanks (illegal settlements)

Riverbanks are easy sites for temporary settlements of workers or formation of slum. Such settlements spread rapidly, destroying the riverbank habitat, and encroaching upon an area where flood water could spread, recede, and recharge ground water or the hyporheic zone. People living here are most vulnerable during floods.

What is required?

Removal of the illegal settlements from the riverside and provide rehabilitation with the help of NGOS

Development projects in " No Development "zones

Illegal Settlements with heavy flood risks

Disturbed feeder stream network

Feeder streams of the rivers are heavily encroached upon, their banks are cemented/ channelized, sewage discharged into them converting the feeder streams into a gutter. During rainy season, these streams with heavily altered storm water carrying capacity, add up in flooding the bankside residential areas.

At some places ground floor of adjacent societies is under water for successive days during high rains, even if flood situation is not there along river.

As development expanded settlement started creeping on foot hill slopes. Cutting and filling of hill slops cause disturbance in natural flow of streams and blocking it due to dumping of construction debris/ waste which indirectly were responsible for non-exist-

Disregarding buffer zone - a function of Natural flood control

ence of streams.

Ambil odha, one of the major feeder streams of Mutha river is heavily encroached with considerable decrease in its channel width. Ambil odha watershed study shows that a large percentage of its first order streams are non-existing now.

What is required?

Making action plan for stepwise removal of encroachment along feeder streams. Removal of concretized banks and stabilization of banks by ecological measures.

Lack of sufficient structured and unstructured drainage of flood waters

Structured Drainage is a system of management of urban water and surface water runoff in a more holistic manner.

Current Pune Drainage system is incredibly old, technologically, and scientifically. Existing drainage systems are insufficient in face of flooding.

What is required?

Incorporate Sustainable Urban Drainage Systems (SuDS) to deliver a more holistic approach to managing surface water and wherever possible mimic natural drainage.

Sustainable drainage is a concept that includes long term environmental and social factors about drainage. It considers quantity and quality of runoff, and the amenity and aesthetic value of surface water in the urban environment.

SuDS manages rainfall close to where it falls. Sustainable Drainage system can be designed to transport surface water, slow runoff down before it enters watercourses. They provide areas to store water in natural contours and can be used to soak (infiltrate) into the ground or evaporated from surface water or transpired from vegetation (evapotranspiration).

Sponge City- Smart City

Increase in hardscape area along river and within city

Ratio of softscape to hardscape is not maintained in green zones of development plans e.g. gardens and other open spaces. In all these areas increased use of paver blocks, playground mats are there which reduces groundwater recharge considerably. Due to these structures, there is increase in run-off contributing to flooding. This adds up to pluvial flooding.

What is required?

Water sensitive urban designs

Sub-watersheds of rivers getting affected due to unplanned development

Large number of new construction projects are coming up in hilly areas in outskirts of Pune, which are sub-watershed areas of the feeder streams of rivers. Such projects alter the sub-watershed character to large extent.

Secondly, EIA studies for such new developmental projects lacks detailed study of seasonal streams and the morphometric analysis of drainage pattern. Seasonal streams are encroached upon during such projects.

What is required?

Improving quality of EIA studies.

Detailed mapping (morphometric analysis) of all such sub-watershed streams in the development plan of Pune, which will assist in not altering the land-use in such cases.

Lack of flood studies

Blue and red line need to be defined after every 20 years and revised maps to be prepared by concerned authorities. This does not seem to be happening.

Lack of flood analysis at local level, lack of creating awareness among public is adding up to more challenges during flood situation.

Need of superimposing PMC storm water management maps and flash flood maps, which will help in clarity of on-groundwork.

Lack of understanding of -

1. Types of flows which need to be managed during floods.
2. Study of type of sediments and amount of deposits in every zone by every stream
3. Mapping of Velocity and hydrograph of every stream as per morphological characters comparing with changed hydrograph of every concretized and channelized stream meeting the rivers.
4. Stages of every river flowing in Pune region. E.g. Young, matured, or premature stage
5. Cross profiles of every stream and tributary.

Flood Mitigation in Subwatersheds

Fewer tress and compacted soils on bank, and straightened river channels which funnel water towards the city as fast as possible are some common problems all over the world. Obviously, there is not enough room especially in areas of flood plain where the cities settle. Water gets squeezed through bridges, between embanked walls putting people and property at risk.

Traditionally, flood defences have included large-scale, hard engineering in and around towns; flood banks and small-scale engineering for rural communities and farmland; and coastal engineering. However instead of reducing the risk, it has increased the risk of flooding.

In countries like Australia, Netherland, UK, US or Norway there is an increasing interest nationally in how the management of the wider landscape can reduce the risk of flooding to cities, towns and villages by slowing the speed of water coming off the hills and temporarily storing water in areas where it will not cause damage. These techniques can be used alongside more traditional methods to reduce reliance on engineered defences and make our catchments more resilient. This could have a significant effect on reducing flood risk without sacrificing production levels or greatly altering land management practices. These measures can also be beneficial to agricultural businesses by reducing the damaging effects of high rainfall events to farms such as soil loss, track erosion or inundation of buildings.

For addressing Urban flooding, a right balance of Natural Flood Management and Structured Flood Management would be a key to manage the floods well and minimize the losses. Refer to Fig. 18.

Natural Flood Management

Guiding principles of Natural flood Management :

1. Slowing water : Reducing velocity and allowing water entering subsurface in source regions
2. Creating close canopy of trees, shrubs, grasses, herbs which will hold soil and reduce flow. planting hedgerows and trees,
3. Loose boulder contour lines along the slopes to reduce velocity of overland flow.
4. Creating buffer strips or zones to percolate water
5. Erosion control measures to reduce sedimentation

Tributaries and stream network of Pune city requires planning, management and execution by understanding the Stream network, morphology, landscape and rainfall pattern in various stretches from source to mouth.

Storing water in flood plains by creating and maintaining carrying capacity of streams, tributaries, bunds, ponds, ditches, swales, or floodplains of river so they fill during rainfall events and empty slowly over 12 to 24 hours.

Reducing surface run offs and Increasing subsurface infiltration by reducing soil erosion : Improving soil structure can increase the depth that water is absorbed to, significantly increasing the volume of water that can be stored in the soil. This will make saturation less likely. The root masses will hold the soil and allow seeping in ground.

Intercepting rainfall : Vegetation, especially tree leaves; intercept rainfall so it does not reach the ground. Water is then evaporated from the leaves, reducing the volume of flood water. Trees can reduce the amount of water reaching the ground.

Structured Flood Management

Conventionally urban storm water runoffs were considered as nuisance and liability. New water – sensitive Urban designs (WSUD) take this as a resource rather than a nuisance or liability. This represents a paradigm shift in the way environmental resources

and water infrastructure is dealt with in the planning and design of towns and cities. WSUD principles regard all streams of water as a resource with diverse impacts on biodiversity, water, land, and the community's recreational and aesthetic enjoyment of waterways.

Creating Easy and cost-effective methods of WSUD which could be replicable in other cities for increasing resilience towards floods and climate change. Water-sensitive urban design (WSUD) is a land planning and engineering design approach which integrates the urban water cycle, including storm water, groundwater and wastewater management and water supply, into urban design to minimize environmental degradation and improve aesthetic and recreational appeal.

Policy and Governance: Space for Rivers

Pune Specific PPI (Policy, Planning, Implementation) :

Mitigation Matters : Policy solutions to reduce local flood risks

1. Policies for
   a. Preserving local water body
   b. Rainwater harvesting and Ground water recharge for bore wells
   c. Roof gardens, terrace gardens, Vertical gardens in residential areas.
   d. Permeable structures along water bodies
   e. Wastewater treatments by Bio retention, Bioswales etc
   f. Creating urban forests, Rain Gardens etc in Commercial places
   g. Developing aesthetic wetlands in new Commercial areas by reuse, recycle etc.
   h. Giving some incentives to farmers to maintain agricultural land and green zones along rivers
   i. Fishing community to be considered under policy
   j. Developing river eco-tourism models by involving agriculture and fishermen community and creating Urban forests.
2. Restrict development in forest or dense vegetation areas and raze structures which are obstructing natural flow of stream channels or find an alternative to it. Development on Hill top and hill slopes should be well thought considering slope and vegetation balance
3. Utilize CSR, CER funding towards protection of green zones, flood plains and other restoration techniques.
4. Plan for River restorations and not for Riverfronts.
5. Introduce Bonds for source region protection and Flood ready Infrastructure
6. Provision for relocating people from flood prone areas with help of NGO's
7. Creating new and innovative revenue sources for mitigation
8. Revival of river regulation policy and timeline for enforcement of the policy to be declared simultaneously.
9. Declaring green zone and buffer zones along river with strict adherence to flood lines and implement changes in Development Plans
10. Upgrading flood lines wrt flood plains and confluences and other buffer zones from time to

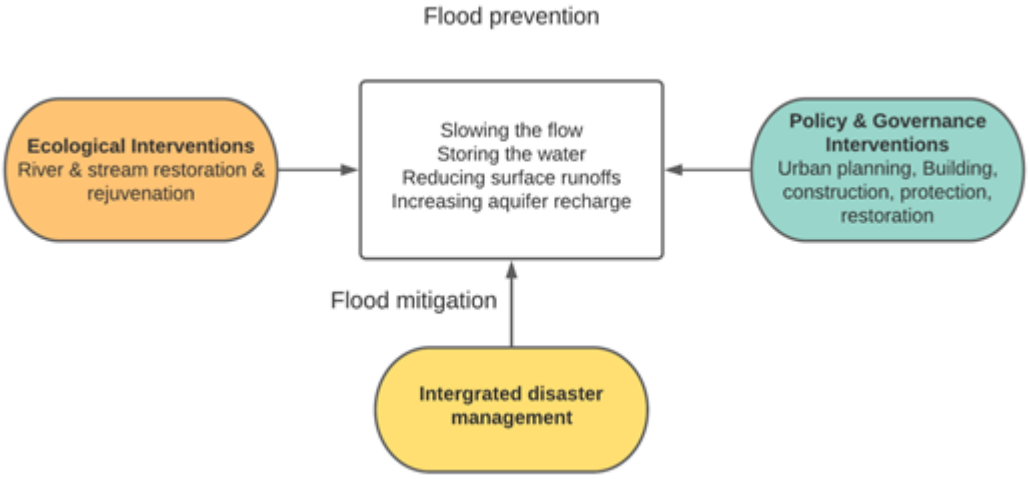


Fig. 18 : Integrated Flood Risk Management

time in catchments of Sub-watersheds after dams. Flood lines to be marked and implemented on ground for Rivers, tributaries, streams, and seasonal drains.

11. To mitigate and control the anthropogenic flooding situation soon, it is imperative to understand aquifer wise natural recharge areas and their disposition with respect to land use pattern and the geomorphic zones that overlie these aquifers.
12. Formation of Pune river monitoring committee for all the riverine areas under the jurisdiction of PMC, PCMC, PMRDA, Cantonment area, in association with NGOs.

Establishing smarter regulations to reduce flood risks

1. All Administrative zones of PMC, PCMC, PMRDA, Gram panchayat to come under one flood zoning map and one flood zone regulation policy
   a. Zoning in 4 categories – Scarp Zone, Spur Zone, Pediment Zone and Riverbanks
   b. Flood lines applicable to all rivers, streams, tributaries.
   c. All wetlands, Lakes, Buffer zones areas to be declared under "No Development Zone" and their areas to be defined and declared in public domain.
   d. All Green zone and buffer zone areas and other flood prone areas as per flood zone regulation policy applicable to rural and urban.
   e. NOC's given to Large development projects in public domain
2. Flood maps, flood line rules, land use prohibitions to be brought in open source using Google maps for quick information.
3. All Legal cases about encroachments must come in Public domain.
4. Existing development to retrofit / modify with New water sensitive design regulations – e.g. Stand alone or Large development projects along the banks must abide by Flood regulations where PMC, PCMC, PMRDA will invest along with owners.
5. Adopting stringent standards for new developments in flood plains- e.g. For new Developments or redevelopments of residential or non-residential structure as per flood zoning maps
6. Enforcement of flood lines and status of land use change through third party in form of NOC's published in public domain.
7. Enforcement of Policy for opting for Water sensitive designs: Use of permeable structures for compound walls, pavements etc instead of concretized structures in source regions, flood plains and in buffer zones. Replacing them with Water sensitive designs.
8. Geotagged location of each storm water chamber and line should be mapped for assessment of flash flood occurrence.
9. Redesigning building embankments along rivers/ streams as they bring more havoc when breached during floods.

Policies for increasing resilience of the City

1. For preserving open spaces along the water bodies by allowing the River and stream corridors space for flow. Provision in budgets to buy spaces for these corridors
2. For Storm water programs in flood plains of high risk. Pediment zones and River zone will require additional buffer zones. Buying of those spaces under different provisions. E.g. For prevention measures under Disaster Management.
3. Create Natural areas buyer Program under CSR/ CER : The Willing Seller-Willing Restorer to run jointly under the Natural Areas Protection Program, which works with owners interested in selling their flood-prone properties with those who wish to restore under CSR/CER funding. E.g. Green zones or Riparian zone need protection. Such places can come under CSR/CER funding. City investing for City's Natural resources.
4. For Provision of funds to remove dumping and debris to be used in new constructions as foundations etc. Corporator's funds/Public participatory funds could be utilized. Alternatively, PMC, PCMC, PMRDA can sell this debris to projects which need filling up.
5. For Implementing Flood line rules in rural areas: should relate to Farming practices, planning of farmlands, for managing green covers. To be incorporated in Grampanchayat areas.
6. For Encouraging landowners to opt for natural solutions to prevent erosion and run offs wherever possible. Farmers can utilize Agro forestry program funding. Increasing green and blue spaces etc.
7. For Existing development to retrofit with water sensitive design regulations – e.g. Stand-alone buildings or large development projects along the banks must co relate with proportion of softscape & flood resistant designs. Green roofs and water harvesting should be encouraged.

8. Adopting stringent standards for new developments in flood plains- For residential and commercial and small or big projects.
9. Policy for opting for Water sensitive designs: Introduction and multiple options for Water sensitive designs for compound walls, roofs, permeable paving, Water harvesting, recycle- reuse compulsory etc.

Planning – Smart City, Sponge City

Incorporating Green Infrastructure, or building "sponge cities," should be a core principle that helps us leverage land use planning while enhancing the effectiveness of flood hazard mitigation. There is a critical need for a framework that brings together these planning activities to bolster the resilience of communities everywhere.

"Sponge cities" focus on mimicking the hydrology that existed pre-development using micro-controls distributed throughout a developed site. These micro-controls are located near the source where runoff is generated and help deliver it back to its natural pathway (through permeable materials into the ground, or through evaporation into the air). Micro-controls can include bioretention filters, green roofs, wetlands, and other devices that reduce both runoff volume and speed. Rain can also be harvested in cisterns for landscape irrigation and other beneficial uses.

Properly implemented Sponge City can reduce frequency and severity of floods, improve water quality, and allow city to save water. Associated strategies like improving Green spaces can improve quality of life, improve air quality, and reduce urban heat Islands there by reducing Carbon footprints for SDG goals. Natural Infrastructure will also help in improving current state of Ground water recharge which is lacking currently.

1. Absorb, clean, and use rainfall in ecologically friendly way to reduce dangerous and polluted run offs. Every unit must absorb its rains in their premises. This can include
   a. Planning of Permeable roads, footpaths, and open landscape areas
   b. Planning of Roof top Gardens, Vertical Gardens, Terrace Gardens, kitchen gardens, Urban forests etc to reduce heat island effect.
   c. Promoting Rainwater harvesting in residential areas
   d. Promoting Rain Gardens in commercial and Institutional spaces
   e. Creating new Green and blue spaces - Lakes, Ponds, wetlands etc could be incorporated in all Govt Institutes, Research Institutes, and other public spaces etc
   f. Maintaining maximum permeable surfaces in areas of flash floods and around confluences.
   g. Promoting Urban Agriculture
2. Planning Natural Urban Infrastructure
   a. Planning for restoring rejuvenating 1st, 2nd, 3rd 4th, 5th order Streams, Rivers, and tributaries
   b. Planning for Improving water quality – By Use of Bio swales, Bio retention techniques etc for improving water quality of storm and sewage drains into Infrastructure
   c. Planning corridors for waterways and restoring their original width and depth by removing all interventions.
   d. Creating Zone wise plans and correlating with Administrative zones:
      i. Scarp Zone
      ii. Spur Zone
      iii. Pediment Zone
      iv. Riverbank
3. Planning for Natural streams and Aquifers:
   To overcome the flooding situation and to restore the natural setup a streams and Aquifers, groundwater recharge is an essential component, which can be achieved by application of ''Managed aquifer recharge'' (MAR) as proposed by ACWADAM. Map of natural recharge areas for Pune's aquifers overlaid on watershed map is given in Section-1 of this report.
4. Protecting Shallow Aquifer System:
   Underground interventions, especially foundations, basements etc. that lead to loss of valuable shallow aquifer storage. NOC given for foundations to be based on maps of Ground water systems.
5. Designating and Creating Solid waste blockers near bridges to obstruct Solid waste entering in rivers.
6. Planning Rehabilitation programs for flood affected: Disaster Management must plan for sufficient budget towards preventive mitigation measures
7. Establish a Flood Prevention Committee Comprising of Ecologist, Hydro geologist, Geologist, Botanist, Biodiversity expert, Urban Planner & Landscape designer with Ecological background and experience etc. Also, to include NGO's working on ground in water sector along with other Govt experts and different Govt departments like Disaster Management, Environment Department,

Police, District Collector, Water & Sanitation dept, Drainage Dept, Revenue Dept etc.

8. Planning for reducing densification of core areas: It is important restricting development in buffer zones and flood plains
9. Well-Planned City and Peri Urban areas: Peri-Urban areas (Fringe villages) need to be well-planned considering concentration on geographical features so haphazard development can be avoided. City planning further to be modified / altered as per population density under each Administrative zone. The corrective measures to be planned for old structures with retrofitting appropriate water sensitive designs-
    a. For densely populated – E.g. Rainwater harvesting, Green roofs, Permeable concrete surfaces to reduce amount of water flowing outside the building.
    b. Moderately populated- e.g. permeable compound walls / Gabion Structures, Maintain proportion of Softscape to hardscape. Sewage drains with Bioswales, Storm drains with permeable material
    c. Sparsely populated – Open spaces to be utilized with Rain Gardens, Open green and blue spaces, Water sensitive Landscapes for Commercial building etc.
10. Inclusion of urban stream restoration Program - (channel development/repairs), watershed development in water budget of local governing bodies.
11. Planning and revising Mapping of flood lines, Natural drains & Streams- Restrict new development along these small streams up to 5 m on both sides. In DCPR Bye laws of Maharashtra it is 9 m from well channelized streams.
12. Create new water sources from existing streams channels/tracks as they are natural and will not cause any problems in future.
13. Detail Channel Geomorphology and spatial study of Study area and upcoming peri-urban areas to find out Constructible and Non- constructible areas and there's also a growing need for channel evolution models that are specifically designed to capture the complexities of urban watersheds and account for the differences in physiographic settings for sustainable development of the region.
14. Create Public / Private River Monitoring system using Apps/Security devices / Security Guards: to keep check on illegal construction and dumping, Solid waste etc along rivers
15. Use of Satellite Remote Sensing: Urban development intensity and spatial extent can be characterized by using satellite remote sensing data through mapping the impervious surface distributions.

Infrastructure

Implementation of all the above concepts by using Natural Infrastructure and Water Sensitive Urban Designs (WSUD) for Structured and non-structured and Restoring Natural water bodies close to original state.

When rain saturates an urban drainage system, the system becomes overwhelmed and water flows into the streets and nearby buildings and homes. This is especially noticeable when the drainage infrastructure is old and in need of repair or replacement. When the water flows (and rises) into the streets, it may cause damage to cars, homes and/or buildings. It also creates potential health hazards from flow velocity and possible pollutants contaminating the water or electrocution due to drowned power lines etc. There are also the inconveniences, like power outages, business closures and disruption of transport services. All these problems are reoccurring in Pune city almost every monsoon.

Surface Water: Pune city has not so far planned or undertaken any proactive measures to adopt with Climate Change. The fact remains that urban areas need to focus more on the root problem: the lack of resiliency in their drainage and sewer infrastructure and the need for progressive, sustainable alternatives for filtering, receiving and storing rainwater. Water sensitive Urban Designs is an answer to many issues to reduce the intensity.

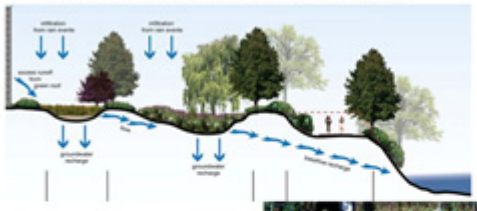
Ground Water: ACWADAM's ongoing studies on Pune's Aquifers (ACWADAM, 2018) also reveal that the development of built infrastructure in the twin municipalities of Pune and Pimpri-Chinchwad covers roughly 200 km2 out of the total area of more than 450 km2. Even at conservative estimates, such infrastructure involves an excavation of at least 2 m, on average, below the vadose zone, i.e. in the shallow aquifer zone. This is evident when many excavations for foundations have needed large-scale dewatering, sometimes over months and years. The volume of such excavated 'aquifer material', therefore, is of the order of 400 million m3. The average specific yield or storativity value of the shallow aquifer (conservative) is 0.001. What this implies is a groundwater storage capacity of 400000 m3 or 400 million litres is reduced due to the progressive increase in infrastructure. In other words, a buffering capacity of 400 million litres is effectively lost just due to this factor apart from the reduced availability of groundwater resources in these two cities.

1. Long term Planning & Management- e.g. Ecological restorations, Improvement in structured drainage system etc
2. Continued / Consistent Management:
   a. Maintenance of drainage lines,
   b. Monitoring and surveillance along banks against encroachments in form of Drone or Mobile App.
   c. Removal of Solid waste Etc.
   d. Monitoring, Maintaining Wetlands, Bioswales, Bioretention treatment areas etc.
      Source Regions : Measures to increase permeability & reduced velocity
   e. by developing closed canopy forests
   f. Maintain/ Increase mosaic character of land use
   g. restoring natural channels as much as possible
   h. No hardscapes/ Concrete structure without mapping aquifers in source regions.
   i. Individual farm owners will not change Natural water Channels
   j. No flattening of landscape
   k. Protection of catchments
3. Flood plains and confluences:
   a. Maintaining river width and Meanders is most important for flood mitigation.
   b. Creating Riparian forests, Green zones to be maintained stringently
   c. Creating series of wetlands and detention basins
   d. At severe damaged banks, embankments with gabion structures without reducing width of river
   e. Ratio of softscape to hardscapes in buildings
   f. Bank stabilisation with canopy vegetation, Green zone protection
   g. No construction along banks in floodplains
   h. Maintain environmental flows as mandated by NGT
   i. Remove in channel construction / obstructions / debris / solid waste
   j. Create vigilant monitoring system for bank protection
   k. Widen, deepen & Free up all streams
   l. No constructions or changing cross section in Red & Blue lines
   m. Planning and restoring seasonal drains and upgrading constructed Drainage system
   n. Reducing siltation by natural bank stabilization and restoring meanders and removing obstructions in flow.
4. Agri- Environment Measures in Rural areas
   a. Utilization of forests to optimum
   b. Using fallow lands for flood control measures
   c. Use of retention and detention ponds
   d. Public awareness and active participation in managing floods
   e. Retaining water through natural media must have priority over soft run off. – Combination

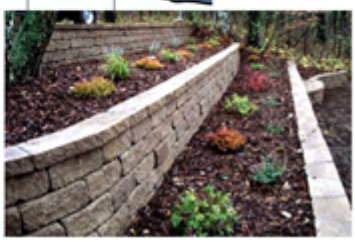
Permeable surfaces as per natural gradient Morphological Characteristics

Rain water harvesting for Moderately dense areas

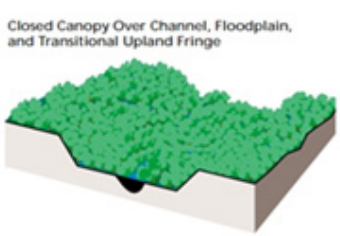
Meandering storm water on hill slopes



Permeable retaining wall on hill slope



Remove Embankment
Replace by permeable structure



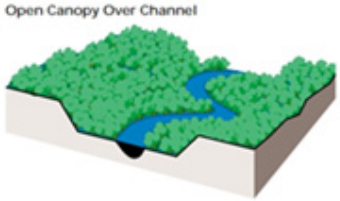


Figure 1.25: Examples of vegetation structure in the stream corridor. *Plant communities play a significant role in determining the condition and vulnerability of the stream corridor.*

of use of detention ponds, retention ponds, wetlands, soil, vegetation as per the local conditions should be used.

f. In event of heavy and lasting rainfall measures to reduce sediment yield could be more beneficial-creating mosaic of forests in a landscape could reduce sediments. – Riparian woodlands and meadows should be encouraged
g. Restore River's natural flood zones

New Urban Infrastructure will require an inclusive approach for increasing resilience of the city to mitigate climate change, meeting SDG goals of Smart city understanding the Natural resources and meeting Urban needs towards Water security, safety, and quality.

Few examples of Urban planning:

Even as India struggles with the water crisis – extreme droughts or extreme floods every year, we have failed to take care of our rivers. Flawed models of natural resource management and careless urban lifestyles have had a disastrous impact on the state of rivers. The River is our most visible source of water and unfortunately the most neglected too.

We must accept and adapt ourselves to the changing climate - shorter spells of intense rains and hotter summers. Pluvial and fluvial flooding are turning river floods more gruesome. Each year, there is loss of life, livelihoods and built capital. Each year crores of Rupees are allocated for disaster management, and yet lost lives are impossible to compensate.

Flooding is a natural characteristic of every river. It is harmful to humans when we disregard the rivers in urban planning, change their channels and build structures within their flood lines. The only way to adapt us to the changing climatic situation is to plan human settlements and activities with the least disruption to Riverine ecosystems. For this, we must make the necessary changes in policy, governance practices and lifestyles of urban citizen.

The rivers are the reason why human settlements have thrived and prospered for centuries, and today their very existence is threatened by human callousness.

(2019 Flood photos : Jeevitnadi team (Tushar Sarode and Shatakshi Gawade))

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Deploying Modern ICT Tools to Develop Gramsabha Level Plans for Conserving and Managing Community Forest Resources

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Abstract

Forest Rights Act 2006 (FRA) gives forest communities rights over collection, storage, processing and sale of non-timber forest produce (NTFP) from their Community Forest Resource (CFR) areas and responsibility of protection, conservation and management of the resources. The Act mandates the gramsabhas to prepare Conservation and Management plans to fulfill these obligations. We present a template of such a plan along with a methodology to prepare it employing user-friendly free and open-source ICT tools which can be used by the tribal youth. The Gramsabha level plans (GSCMP) differ significantly from the Forest Department Working Plans (FDWP) in several ways: (a) FDWP is concerned mainly with timber extraction and plantation, whereas GSCMP emphasize sustainable collection, processing and sale of NTFP and conservation of biodiversity and (b) FDWP is based on outdated methodology, whereas the proposed GSCMP employs the modern landscape perspective and plotless sampling methods. This methodology is already being used in 17 gramsabhas of Gadchiroli district of Maharashtra.

Key words: Forest, Community, Rights, Conservation, Management, Plan

Community Forest Rights

In 2006 the Indian parliament enacted the Forest Rights Act (FRA 2006) undoing a historical injustice and recognizing the rights of the scheduled tribes and other traditional forest dwellers on forest resources. The Act provides for three kinds of rights; firstly on land under cultivation up to 4 ha, secondly on land for community facilities such as burial grounds or schools up to 10 ha and most importantly on lands on which the communities have traditionally depended without any upper limit on the areas assigned. As of February 2019, more than 6000 Gramsabhas have been granted community rights covering more than 10 lakhs ha in the state of Maharashtra (Pers. Communication Maharashtra Government, Department of Tribal Development 2020). However, this statistics confounds limited area rights for community facilities and management rights over NTFP. Hence, it is unclear as to how many of these represent the really significant forest resource management rights assigned to Gramsabhas. At least in Gadchiroli district a large proportion are genuine management rights, hereafter referred to as CFR rights and these are the subject of discussion of the rest of the paper.

The challenge

The model before us to prepare the Gramsabha Conservation and Management Plan (GSCMP) is the Forest Department Working Plans (FDWPs). Gramsabha plans have a focus on NTFP as the Gramsabhas have ownership rights over NTFP, the plan also needs to provide for sustainable harvesting of NTFP, their processing, value addition, sales, main-

tenance of accounts, payment of taxes. However, FDWPs have rather different and limited objectives as they are focused on extraction of timber and on organizing new plantations. They do not concern themselves with further processing and sale of the timber, since those are the functions of other wings of the forest department. Even within these limitations, the FDWP are flawed and have not resulted in sustainable use of forest resources on a scientific basis (Gadgil and Rathore 2015, Nair 1984). The plans are grounded in forest stock enumeration. Their methodology has changed little from 1910 and does not take into consideration recent scientific developments such as a focus on landscape elements or statistically superior plotless sampling methods such as point centered quarter transects. FDWP pay scant attention to management of non-timber forest resources and conservation of biodiversity. The Indian Institute of Forest Management at Bhopal had initiated the preparation of a manual on sustainable harvest of minor forest produce. Only a draft of this manual is available providing very general prescriptions not based on any careful experimental studies. Furthermore, the manual did not go beyond the draft and the project has been subsequently abandoned (Personal Communication, IIFM 2019). Hence no expert guidance is available to gramsabhas on sustainable management of non-timber forest produce on which the GSCMP are focused. The Mendha(Lekha) gramsabha was granted CFR rights in 2009 and since that time has been requesting Forest Department for pertinent background information such as the results of their line transect-based enumerations and maps. The data is not available for scientific scrutiny or verification for over a decade leading to serious doubts as to the authenticity of the forest department data.

In contrast, the GSCMP with which we are concerned have to adopt a very different approach. These plans must address issues of sustainable management of NTFP including commercially valuable resources such as bamboo, tendu leaves, mahua flowers and seeds, chironji, medicinal plants such as harada, beheda, amla and shatavari. The community members do have an in-depth understanding of the ecology of these plant species and of the local ecosystems. This information is vital for preparation of appropriate plans which must necessarily be locality and time specific since the resource endowments of different gramsabhas even in close neighborhood vary a great deal from village to village. The long-term experiences of the local community in management of these resources, including traditions of conservation and sustainable use also provide useful pointers, but these need to be supplemented in coming days by careful experimental studies such as on regimes of sustainable harvest of bamboo culms. It may be noted that FD prescriptions in this context are invalid (Prasad and Gadgil 1981).

Moreover, GSCMP requires certain proper quantitative estimates, for instance, to effectively market resources like bamboos and tendu leaves though tendering and auctioning. GSCMP must also provide for undertaking local level processing and value addition, maintenance of accounts and payment of taxes. These, too, require inputs from outside experts at least in the initial phases.

At the same time, there are today important newly emerging strengths on which the gramsabha members can draw. Smartphones equipped with powerful Apps are now widely available even in remote tribal villages and the youth are very adept at using them. For instance, with their help they can access Google Earth images and delineate CFR or individual landscape element boundaries on these images. All these facilities are now available in Marathi or other local languages so that the lack of knowledge of English is no more a barrier. Communication of pertinent information has also become very easy through mobile-based Apps such as WhatsApp. Other valuable tools are platforms for online collection and management of various types of data including numerical, text, photographs and geographical coordinates.

Methodology

Our methodology is grounded in using one particular online data collection platform, namely Epicollect5 (https://five.epicollect.net/) originally created by Oxford University to study epidemics, for collecting data and create plan documents. Different entry forms developed on this platform go into making of a template of GSCMP. This template has evolved as a result of our experimenting over 2 years working closely with the local youth who were trained by us through a 5-month long Mumbai University Diploma programme for nominees of CFR holding gramsabhas (Gadgil, 2020) held at the field site of Mendha(Lekha) with its 1800 ha CFR area.

The entry forms and Information gathered

There are two sections of the Plan – A) stock taking of the resources and B) Planning for conservation and management.

The input forms for stock taking capture the following ecological data along with whatever information

that is available on the regime for sustainably harvesting the resource. We treat the forest under study as a patch-work of landscape elements (LSEs) of various types (Wikipedia article on Landscape ecology). Using such LSEs as a basis for sampling by employing a plotless method such as Point Centered Quarter Method is a very efficient method for quantitative assessment of species abundances (Mitchell, 2007).

Following information/data is collected using 6 different entry forms (CFR_CMP_1 through CFR_CMP_6) created for section A of plan document :

a) Details of the Gramsabha like its block, district, census code, physical location i.e. lat-long of office of the Gramsabha, photograph of allotment letter, details of resource rights, name of a gpx file of boundary demarcation etc.

b) Background – aims and objectives of GSCMP and organizational structure of the Gramsabha.

c) History of the village,

d) Rules for self-governance for sustainable use of resources. These include (i) rules for harvesting different resources for self-use, regulation of external users and for commercial purposes, (ii) rules for cattle grazing, patrolling, tackling emergencies like forest fires, maintenance of fire-lines (iii) rules for book-keeping and financial transactions for community based activities like auction of bamboo or value addition and sale of any NTFP (iv) conservation measures such as managing nature reserves.

e) List of available maps like village map with Land Record office, Toposheet, forest map showing compartments and Google map showing CFR boundary. Names of all adjacent villages.

f) List of forest compartments within the CFR area.

g) Land use and conditions of boundaries.

h) Historical rainfall records

i) List of 'Tapus', or patches of land/ water delineated by community members

j) List of LSE patches inside CFR and village boundary and their areas, location etc.

k) List of all known plant species within the boundary of CFR area along with their habit, habitat, natural or/and cultivated and qualitative abundance.

l) Utility of the plant species – names of plant species along with different uses like food, fodder, medicine, construction for household consumption as well as marketing along with harvesting practices, storage processing if outsourced and possible nuisance value.

m) Details of LSE patches viz. their geological locations, type of terrain, tapus covered, human intervention and important plant species

n) Quantitative estimates of important tree species employing Point Centered Quarter Method for LSE patches.

o) Quantitative estimates of important herb species employing 1meter x 1 meter quadrats on various LSE patches.

p) Quantitative estimates of bamboos categorized into different age groups in various LSE patches

p) List of rare, endangered and threatened species along with their past and present status, reasons for their diminishing abundance, efforts, if any, to protect them etc.

q) Qualitative abundance of plants on privately owned lands

r) List along with estimates of qualitative abundance of wild animals in the CFR area.

s) Following information for each of the species harvested: species name, part harvested, use for which harvested, method of sustainable harvesting, value addition done if any and disposal method.

Following are the details for activities to be undertaken for the section B of plan document to be noted using Form CFR_CMP_7 :

Sustainable harvesting of NTFP :

a) Details of Bamboo felling series including estimated number that may be harvested. Arrangements of engaging manpower for cutting, transporting, stacking and sales. Estimated cost for each item and revenue projection.

b) Details of methods of sustainable harvesting of each NTFP species including species of medicinal uses.

Works to be undertaken under MNREGA (MNREG Act 2005) :

1) Detailed description of the proposed nursery including location, area, source of water, fencing, names of species and number of saplings species-wise and labour-days required per year.

2) Details of proposed plantations including locations, watering arrangement during stress period in first year and labour-days.

4) Details of works to be undertaken for soil-water conservation under MNREGA.

5) Details of works to be undertaken for maintenance of tanks to be undertaken under MNREGA.

6) Details of planning for construction and maintenance of roads inside forested area for transport of material, patrolling and emergencies like forest-fire to be undertaken under MNREGA.

7) Maintenance of fire-lines under MNREGA

8) Table for cost estimation and time-line : item-wise material cost, labour-days, labour cost, supervision

cost, date of inception and completion of proposed works.

Process

Data is captured on the field, entered in forms listed above and uploaded incrementally as when feasible. This data is saved on the freely accessible central server of Epicollect platform and may be downloaded when a form is completed. It may then be converted to a word document which may be edited.

Although we have tried to bring on board most of the aspects of Conservation and Management Plan, some quantitative parameters listed below need to be derived from certain observations listed above. We will make user friendly application/ solution available for this purpose.

1. Tree density : Total number of trees per hector as well as species-wise number per hector.
2. Bamboo availability in different LSE types : number of bamboo poles of different age and size per hector.
3. Availability important herbs.

Conclusions and way ahead

Today's youth are the third generation after independence. Although our governments have paid scant attention to providing good education to all our people, members of this third generation even from remote rural areas and from disadvantaged sections of the population have acquired enough basic education to be able to take advantage of the modern facilities of access to and exchange of information through the now quite affordable smartphones. The companies that are providing the instruments such as Samsung or internet based services such as Google, Facebook and WhatsApp have created user friendly facilities for use of Indian languages, photographs, audio clips and video clips to serve their own commercial interests. These can be put to manifold uses including acquiring information about and developing GSCMP.

Our own appreciation of the potential of modern communication facilities has developed over a period of 10 years beginning with the preparation of Mendha (Lekha) forest working scheme in 2010. We have worked on and now arrived at a good template for GLCMP in collaboration with 17 diploma holders. Fairly soon GLCMPs using this template will be ready. This template may now be widely employed not only using English or Marathi but using other local languages as appropriate in other states of India as well. At the same time the GLCMPs would serve as possible exemplars.

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Birds of a Polluted River

Prakash Gole

The Mutha river meanders through Pune City for a distance of over 6.5 km from Vitthalwadi to the South-west, to the Sangam in the northeast, before it merges into the MuIa at the latter place. The joint stream then flows for a distance of 4 kilometers before it leaves the city-limits.

I have been watching birds along these stretches of the rivers for well over fifteen years, i.e. since the mid-sixties. This article however, while taking note of some of the major changes noted over all these years, is primarily based on systematic observations made over a period of over six months, i.e. from October 1982 to April 1983.

Special mention should be made of the tail- end portion of the MuIa-Mutha, where the joint stream leaves the city-limits. This 1.5 km stretch of the MuIa-Mutha now constitutes the Mula-Mutha Bird Sanctuary inaugurated by Dr. Salim Ali in 1977. The Sanctuary deserves separate treatment on account of the numbers and variety of birds found there in winter and spring.

Quality of River-Waters

It is generally believed that the water of both the rivers is polluted. Sewage overflows into the rivers at many points and industrial effluents also drain into the rivers. To gauge the extent of pollution, water-samples were collected at many points along the river-course. For chemical analysis of water a five-liter sample was collected from each of the points and 250 cc samples were used for the MPN count. Tables lA and 1B show results of the analysis of water-samples. The names of collection points are also given in the tables and the same can be seen on maps. To compare the quality of water of the rivers with that of other water-bodies, samples were also collected from the Khadakwasla reservoir upstream on the river Mutha and from Ambil Odha, a stream that meets the Mutha in the city.

It will be seen from Table lA that as the river flows from Vitthalwadi to the Sangam the proportion of solids, Dissolved solids, COD, BOD and Chlorides goes on increasing which indicates that the river is receiving higher and higher loads of organic matter. This is due to the increase in the number of sewage overflows going into the river. The oxygen content is mostly low. The water of Ambil Odha which flows through densely populated areas and on whose banks a number of hutment colonies are located, brings into the river even greater loads of pollution. It is also worth noting that samples from the Mula and the Mula-Mutha also show a higher concentration of pollution and compare favorably with the Odha.

Table No. 1B shows the results of the MPN count. Predictably the analysis shows an increasing concentration of organisms per 100 ml as the river flows from Vitthalwadi to Sangam Bridge.

The conspicuous rise in coli- form MPN indicates faecal pollution. This makes the water highly dangerous to human beings and activities such as bathing, washing clothes and utensils, which are normally carried out by citizens on the river, are fraught with danger of infection. However, as will be seen from the discussion that follows, this water, which carries a great load of organic matter, may not necessarily be dangerous to birds. Indeed it appears that certain species of birds thrive on it.

Broad Habitat-Types along the River Course

The 6.5 km stretch of the Mutha and the further 4 km stretch of the Mula-Mutha exhibit a variety of habitats. They are: 1) Deep water; 2) Shallow water; 3) Marshy land; 4) Grassland; 5) Rocks and boulders, and 6) Dryland and scrub. Riverside trees also constitute a distinct habitat, though arboreal birds are not considered here. Let us now see the characteristic bird-life of each of these habitats. The broad extent of each of these habitats is shown in the maps.

Table 1A

Chemical and Bacteriological Analysis of Water Samples Collected at Different Points along the Rivers in Pune City

NO. OF COLLECTING STATION ALONG THE MUTHA, THE MULA & THE MULA-MUTHA											
Count of	1	2	3	4	5	6	7	8	9	10	Names Of Stations
Turbidity(ppm)	07	16	06	12	11	09	14	11	08	15	1=Khadakwasla Reservoir
Total Solids (mg/litre)	108	120	100	168	184	200	252	322	190	334	2=Upstream of Vitthalwadi
Dissolved Solids (mg/1)	108	108	100	148	167	191	246	218	180	292	3= Opp. Pumping Station
C O D	10	04	24	25	21	05	78	70	19	150	4=Upstream of Garware Causeway
B O D	03	01	07	07	06	02	30	22	07	40	5=Near Shinde Bridge
Dissolved Oxygen	4.20	1.40	4. 60	4. 20	5. 20	4. 30	2. 90	2. 40	1.30	3.0	6=Upstream Dengle Bridge
Nitrates (N205)	-	-	-	-	-	-	-	-	-	2	7=Downstream Holkar Br.(on the Mula)
Nitrates (N203)	-	-	-	-	-	-	-	-	-	-	8= Downstream Sangam Br. (on the Mula-Mutha)
Chlorides (CI)	14	8	21	21	21	28	35	42	49.5	35	9=In Bird Sanctuary 10=In Ambil Odha

Table 1B

Bacteriological Count of Water Collected at Different Points along the Rivers in Pune City
M P N Results: Count per 100 ml of water

Sample Collected at	Date	Count
1. Upstream of V.wadi	22.3.83	1.4 x 10
2. Opp. Pumping Station	25.3.83	2.0 x 10
3. Below Garware Causeway	22.3.83	2. 5 x 10
4. Near Natraj Causeway	22.3.83	1. 3 x 10
5. Below Omkareshwar Temple	22.3.83	1. 3x 10
6. Below Shivaji Bridge	22.3.83	3.5x 10
7. Below the Sangam	6.4.83	1. 5x 10
8. In the Mula River	6.4.83	1.0 x 10
9. In Bird Sanctuary	24.3.83	3.5x 10

Deep-Water Habitat

The Mutha river within Pune city is shallow with an average depth of less than a meter. In certain places, however, deepish pools are formed, e.g. near Vitthalwadi, near Omkareshwar Temple, and near the Sangam. The Mula is a bigger river and the stretch between Holkar Bridge and Sangam is deeper (average depth about 2 metres). The joint flow below Sangam is of considerable depth too, due to impoundment near Bund Garden. The river- flow is again shallow in the Bird Sanctuary.

The common submerged plants occurring in this habitat are : Hydrilla verticillata, Lemna gibba, Ceratophyllum demersum, Vallisneria spiralis, Spirodela polyrhiza etc. Eichhornia crassipes became progressively dominant after October, especially in the Mula and by March it had almost covered the open water in the Bird Sanctuary. Another obnoxious weed Pistia stratiotes was also recorded at a few places especially on the Mula.

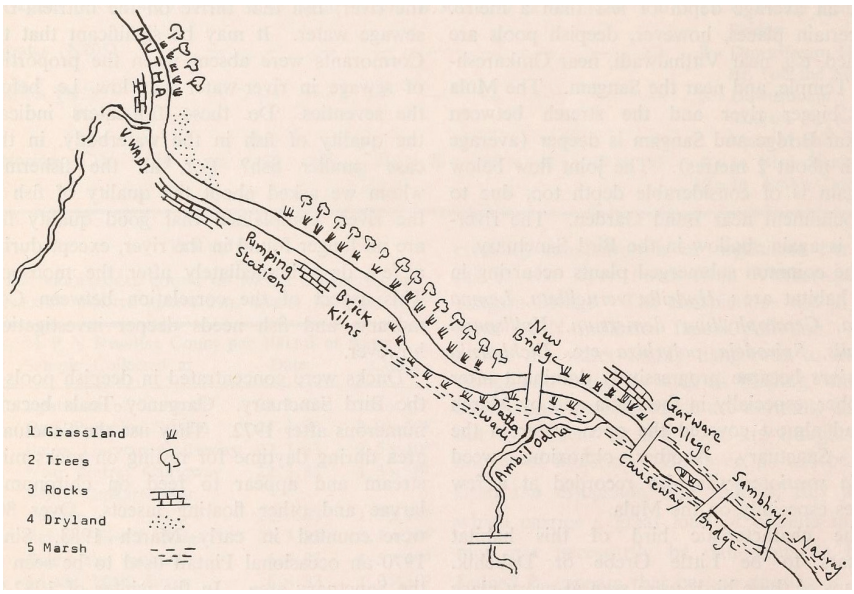
The characteristic bird of this habitat appears to be Little Grebe or Dabchik. Groups of these birds were seen at every place on the Mutha where there is deepish water.

The stretch of the Mula considered here does not hold any Dabchik perhaps due to lack of aquatic food and movement of boats in the river. Upstream of Garware causeway these birds were seen to breed from February on-wards on little platforms made up of aquatic plants ‹Hydrilla) and floating debris. Three nests and a pair with two chicks were seen in the last week of February 1983.

Coots, Little Cormorants, a few Large Cormorants and ducks like Garganey Teals, Pintails and Shovellers were the other birds that belonged to this habitat. The Cormorants are a recent addition to the river fauna. The Little Cormorants started appearing on the river since 1969 and the Large ones came as recently as 1980. They perhaps reflect the abundance of small and medium-size fish in the river; fish that thrive on the nutrient-rich sewage water. It may be significant that the Cormorants were absent when the proportion of sewage in river-water was low, i.e. before the seventies. Do these fish-eaters indicate the quality of fish in the waterbody, in this case smaller fish? For, all the fishermen whom we asked about the quality of fish in the river, complained that good quality fish are no longer found in the river, except during a few days immediately after the monsoon. This aspect of the correlation between Cormorants and fish needs deeper investigation, however.

Ducks were concentrated in deepish pools in the Bird Sanctuary. Garganey Teals became numerous after 1972. They use the Sanctuary area during daytime for resting on rocks mid- stream and appear to feed on chironomus larvae and other floating insects. Over 800 were counted in early March 1983. Since 1970 an occasional Pintail used to be seen in the Sanctuary area. In the winter of 1982-83 their number was the highest recorded so far.

A few Shovellers with the colorful males outnumber-



Map 1 : Habitats along the Mutha

ing females are to be seen in the Sanctuary every winter. They feed on floating aquatic insects.

Shallow-Water Habitat

Most of the stretch of the Mutha river considered here, being shallow, this habitat covers probably the greater part of the river ecosystem. The water is shallow, at places even midstream, and there are rocky outcrops, islands, floating vegetation and other debris which the birds can take advantage of, while wading through shallow water.

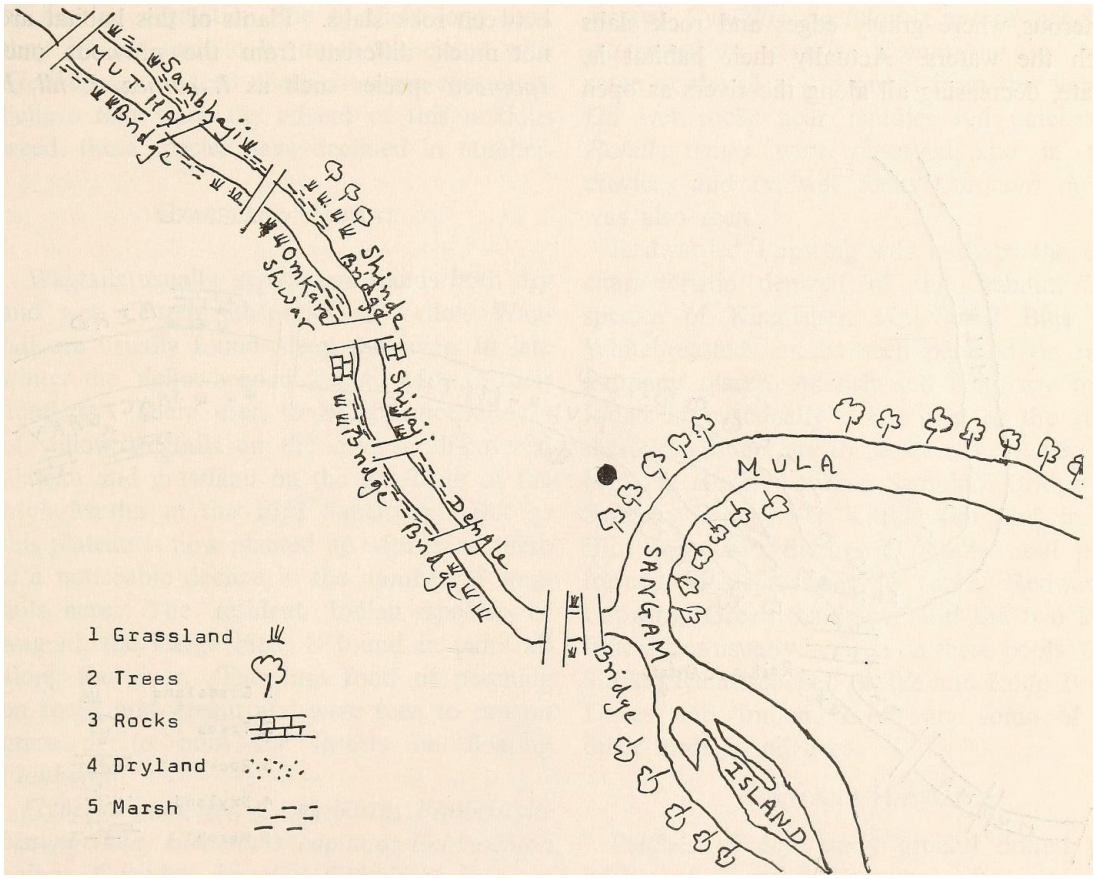
Plants of this habitat include partly submerged plants, plants growing at the edge of water and those growing along drains and other effluents flowing into the river. Cryptocoryne retrospirallis, Xanthium strumarium, Ammania baccifera, Commelina sp., Cyperus pangorei, Polygonum glabrum, Asclepias curassavica, Hygrophila auriculata etc. were seen to be common here.

Typha angustata, Jussiaea suffruticosa, Crinum defixum, Bacopa monnieri, Phyllanthus niruri, Ricinus communis and Ipomoea palmata were the common plants seen growing around sewage overflows and effluents.

The most characteristic birds of this habitat are the long-legged herons and stilts. The numbers of egrets and Black- winged stilts have risen considerably in recent years on the rivers. Intermediate and Little egrets are more common than the cattle egrets which were mostly seen around sewage overflows and accompanying cattle.

The egrets perch on rocks, islands and floating debris including the weed Eichhornia and were also seen to congregate around streams that pour a tremendous load of faecal contamination into the rivers.

Pond herons are more solitary than egrets. They feed at the edges of water and in dense masses of Eichhornia. By the beginning of April some cattle and little egrets came into breeding plumage. Large egrets, Grey and Purple herons, and occasionally an open billed stork and a White ibis were noted in this habitat, especially on the quieter stretches of the Mutha, i.e.



Map 2 : Habitats along the Mutha and the Mula

between Dattawadi and the Pumping Station and in Bird Sanctuary. While the larger herons appeared to feed mainly on fish, egrets and pond herons were seen to catch insects from the vegetation at the edge and on islands. All the herons are only fair weather inhabitants of the rivers and disappear completely in June and July and reappear by August-end.

Blackwinged stilts are also a comparatively recent addition to the river fauna.

They were detected in some numbers in 1968-69 and since then their number has been increasing year by year. Their flocks are to be invariably met with near sewage outflows and in and around streams that pour sewage in the river. They arrive by the end of September every year and their peak numbers are reached in January. In January 1983 over 2000 could be seen on the rivers.

Three species of Sandpiper, viz. Common, Green and Spotted, Little stint, Greenshank, Ruff and reeve, Little Ringed Plover etc. are the other birds seen in this habitat. They are numerous where grassy edges and rock slabs touch the waters. Actually their habitat is, of late, decreasing all along the rivers as open water near the edges is being covered by Eichhornia especially in the Bird Sanctuary. Egrets, pond .herons, wagtails and to a lesser extent sandpipers feed on mosquitoes, spiders and beetles hiding in its leaves. Yellow and White wagtails and to a lesser extent Large Pied Wagtail are thus found not only on the patches of turf and rock along the rivers but also on the floating water hyacinth.

Marshy Habitat

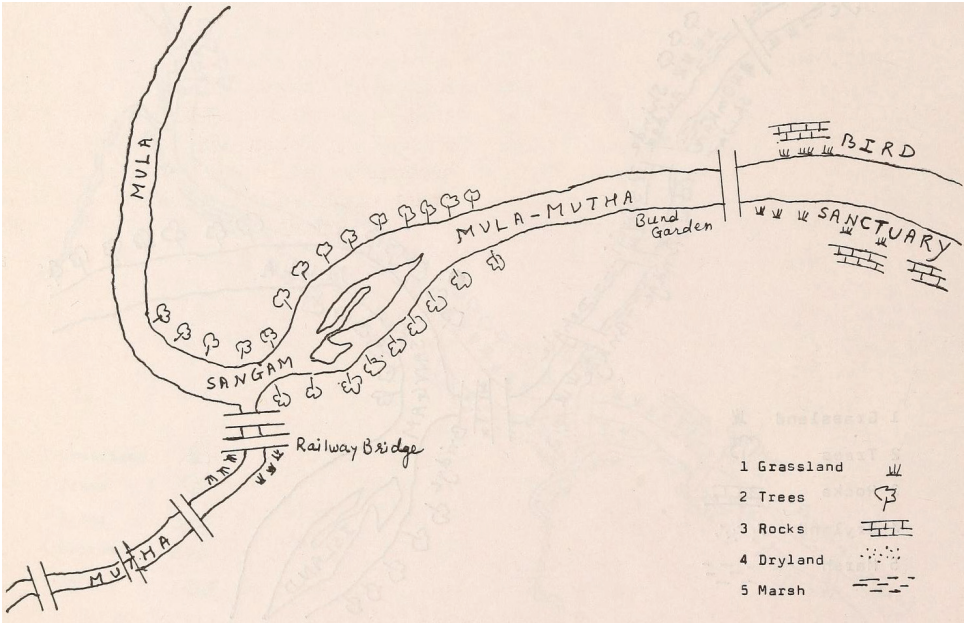
Water-logged areas are thinly spread along the rivers, especially where bays and inlets are formed and where there are depressions between rock slabs. Plants of this habitat are not much different from the previous one. Ipomoea species such as I. carnea, I. nil, I. muricata were recorded commonly in marshy areas.

Also *Marselia, Rorippa indica, Homonia riparia* were recorded, from marshy places.

The characteristic bird of this habitat was seen to be Snipe (Fantail or Pintail?) and to some extent Painted Snipes were usually found hidden in the short, wet grass. Where the grass is taller and typha stands abound, hide Purple and Indian moorhens. Bronze-winged and Pheasant-tailed Jacanas used to be found on the river some years ago. The former has now completely vanished while the latter is seen in decreasing numbers year by year. Though these birds can take advantage of floating vegetation due to their long toes, they are not seen to be much associated with Eichhornia. Indeed there is some reason to believe that since the advent of this noxious weed, these species have declined in number.

Grassland Habitat

Wagtails usually exploit grasslands both dry and wet. Three subspecies of Yellow Wagtail are usually found along the river. In late winter the Yellowheaded wagtail adds to their numbers. There used to be enor-



Map 3 : Habitats along the Mula-Mutha

mous flocks of yellow wagtails on the dry, scrub-covered plateau and grassland on the left bank of the Mula-Mutha in the Bird Sanctuary. But as this plateau is now planted up with trees, there is a noticeable decline in the number of wagtails here. The resident Indian species of wagtail, the Large Pied, is found in pairs all along the river. They are fond of perching on rocks mid-stream and were seen to run on grass or to hunt for insects on floating Eichhornia

Cyperus pangorei, C. globosus, Fimbristylis bisumbellata, Eleocharis capitata, Echinochloa colona, Cynodon dactylon, Chloris barbata are some of the typical plants of this habitat.

Rocky Habitat

Rocks are exposed in several places along the Mutha. At Vitthalwadi there is a broad platform of basalt on the right bank. There is also a broad and high rocky platform on the left of the Mula-Mutha in the Bird Sanctuary. In between there are rock exposures on both the banks of the Mutha and rocky outcrops in the shallow river-bed. The deeper Mula does not show rocky exposures on either its banks within city limits or mid-stream.

Plants growing in rock crevices and between gaps in rocks were found to be mostly grasses. Cynodon dactylon, Cyperus pangorei, Alternanthera sessilis, Commelina sp. were some of the plants recorded from this habitat. On wet rocks near puddles red patches of Rotella tenuis were observed and in rock crevices and on wet rocks Canscora diffusa was also seen.

Redwattled Lapwing was perhaps the most characteristic denizen of this habitat. Two species of Kingfisher, viz. Small Blue and Whitebreasted can be seen perched on rocks at many places. As fish and frogs are to be found in practically every part of the rivers these kingfishers are to be seen everywhere except the stretch between Sambhaji Bridge and Sangam Bridge. At Vitthalwadi and in the Bird Sanctuary there are puddles and pools formed in depressions in rocks. Redwattled Lapwing, Green Sandpiper and the two kingfishers can usually be seen on these pools. Grey Shrike, Rufousbacked Shrike and Little Brown Doves and Indian Robin are some of the other birds found here.

Dryland Habitat

Patches of dry, stony ground dotted with bushes of Lantana, Calotropis, Pongamia etc. can also be found along the Mutha river.

On one such plateau in the Bird Sanctuary, trees such as Erythrina sp., Bauhinia sp., Cassia sp., Bombax ceiba, Cochlospermum religiosum, etc. are now planted.

Small bushes and stunted trees provide convenient perches for a number of bird species. Rufousbacked Shrike, Common Green Bee-eater, Stonechat, Black Drongo, Large Grey Babblers are normally seen to take advantage of these. Crows and Common Mynas are attracted to these dry, dusty patches on account of the movement of men and their cattle. The Common Myna has some favourite roosting trees along the river. Before flying into these trees at dusk the Mynas use these dry slopes as gathering stops where they assemble in enormous numbers moving into the roosting trees before sunset.

Commuting Birds and Birds Seen in Flight

The broad river channel of the Mutha appears to provide a route to commuting birds. In the morning Little Cormorants, Little and Cattle and Intermediate Egrets, Common Mynas and to a lesser extent Roseringed parakeets appear to follow the river on their foraging trips. They take the reverse route in the evening. Pied Kingfishers are fond of traveling a great deal along the river course. They favour the deepish pools, perching on wires running across the river or scanning the water surface by hovering in the air. They probably require a transparent surface and consequently were seen to be common at places where the turbidity index was low. In their beats up and down the river they rarely stop to hover between Sambhaji Bridge and Sangam. GuIlbilled terns and Marsh Harriers patrol the river to and fro. The terns pick up insects and floating debris from the surface while the Harrier looks for larger prey. House Swifts, Eastern Common and Redrumped Swallows and sometimes Little Pratincoles are seen to hawk insects in the air.

Trees lining the banks between Vitthalwadi and Dattawadi Bridge and again in the Bird Sanctuary area are seen to be patronised by such arboreal birds as Grey Hornbill, Golden Oriole, Koel, Crimsonbreasted Barbet, lora, Grey Tit, Crow-Pheasant, Small Minivet etc. Even the call of the Grey Partridge could be heard from cultivation opposite the Pumping Station and near the Bird Sanctuary.

The Winter of 1982-83

Between October 1982 and April 1983 systematic observation and counts of birds were carried out on the river Mutha and in the Bird Sanctuary on the Mula-Mutha. Birds were counted once every month while certain species were singled out for more intensive counts and observations. During this period 71 species

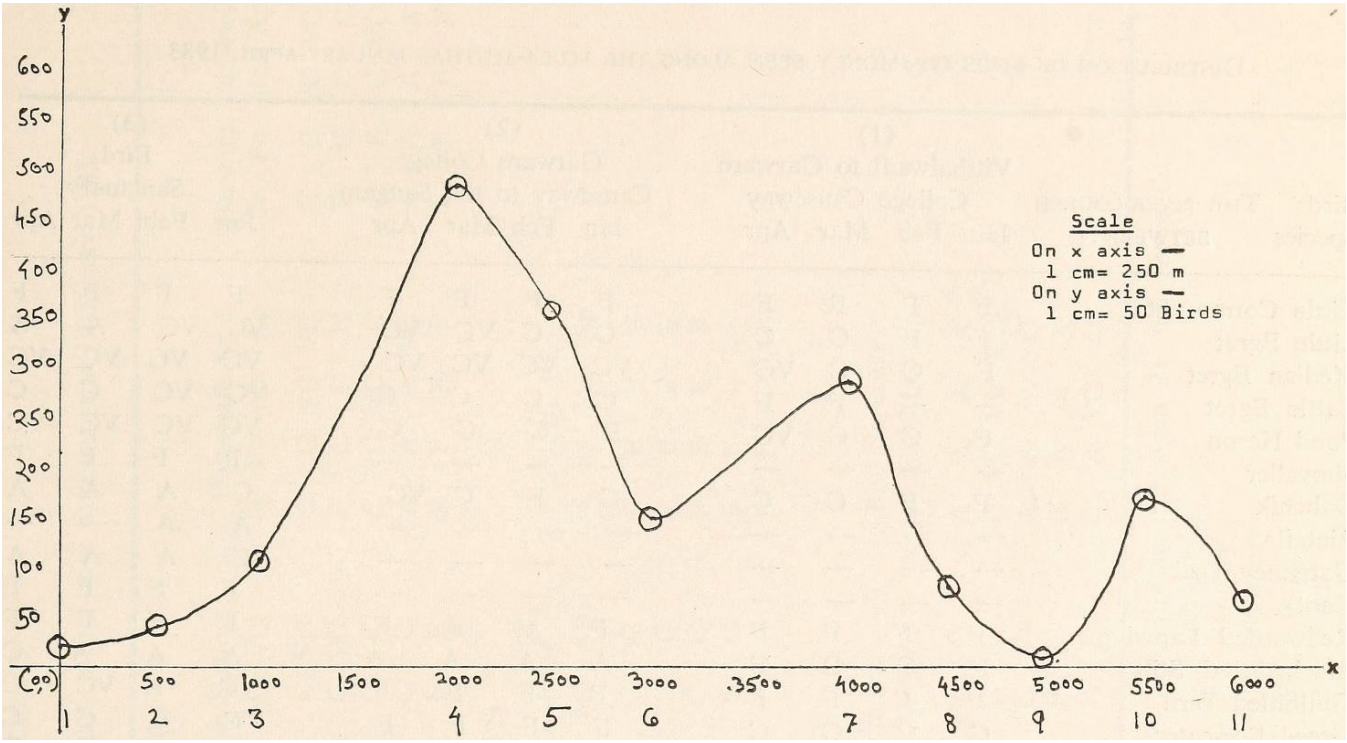


Fig.1. Distribution of Birds along the river.

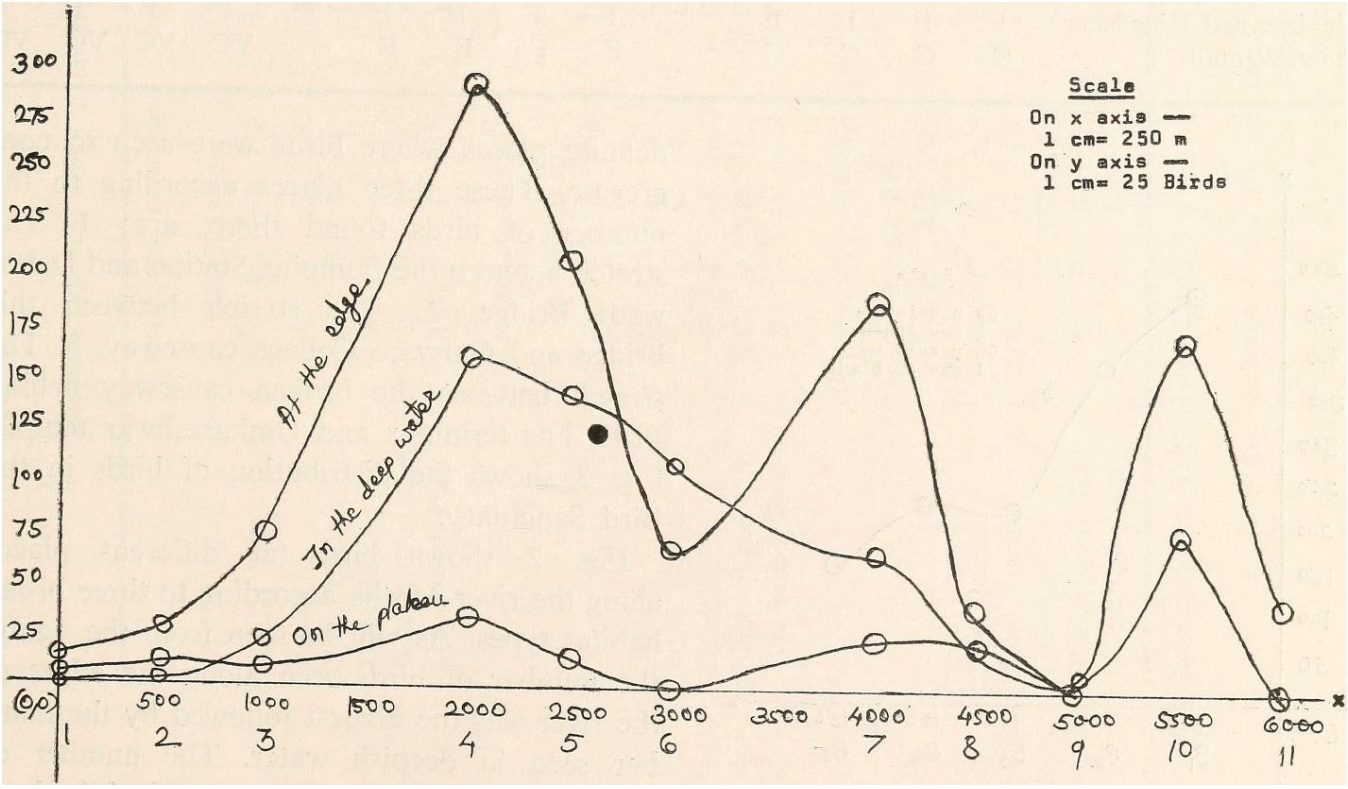


Fig. 2. Distribution of Birds along the river according to Habitat.

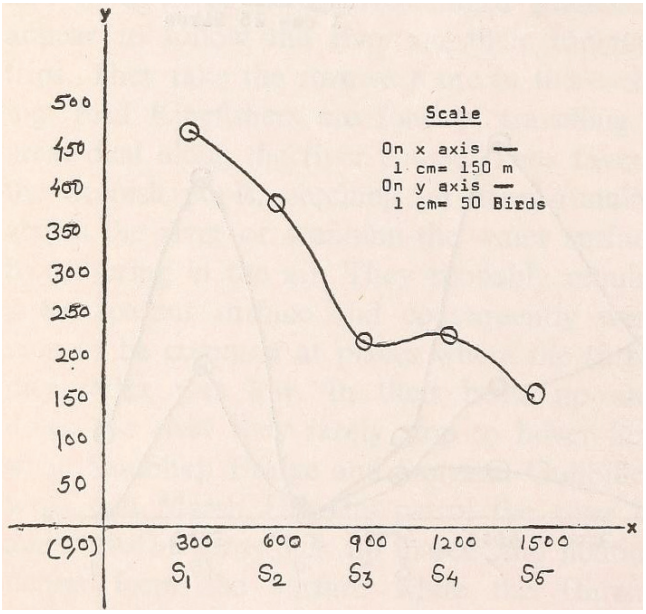


Fig. 3. Distribution of Birds in the Bird Sanctuary.

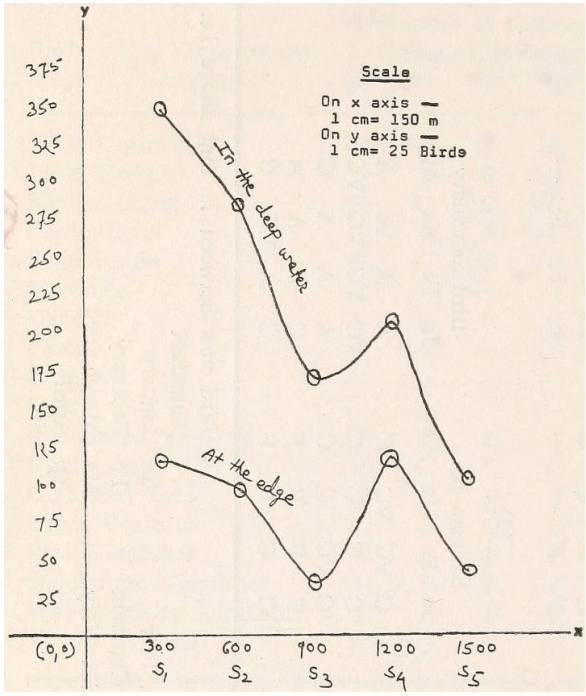


Fig. 4. Distribution of Birds in the Bird Sanctuary according to Habitat.

Table 2

Distribution of Birds Commonly Seen along the Mula-Mutha, January-April 1983

Bird Species	THE RIVER-COURSE BETWEEN : (1) Vitthalwadi to Garware College Causeway				(2) Garware College Causeway to the Sangam				(3) Bird Sanctuary			
	Jan	Feb	Mar	Apr	Jan	Feb	Mar	Apr	Jan	Feb	Mar	Apr
Little Cormorant	F	F	F	F	F	F	F	F	F	F	F	F
Little Egret	F	F	C	C	C	C	VC	VC	VC	VC	A	A
Median Egret	F	C	C	VC	VC	VC	VC	VC	VC	VC	VC	VC
Cattle Egret	-	-	F	F	C	C	C	C	VC	VC	C	C
Pond Heron	F	C	C	VC	F	C	C	C	VC	VC	VC	VC
Shoveller	-	-	-	-	-	-	-	-	F	F	F	F
Dabchik	F	F	C	C	C	F	C	VC	C	A	A	A
Pintail	-	-	-	-	-	-	-	-	A	A	-	-
Garganey Teal	-	-	-	-	-	-	-	-	VC	A	A	A
Coot	-	-	-	-	-	-	-	-	F	F	F	F
Redwattled Lapwing	F	F	F	F	F	F	F	F	F	F	F	F
Blackwinged Stilt	F	C	C	C	A	A	A	A	A	A	A	C
Gullbilled Tern	F	F	F	F	F	F	F	F	C	A	VC	C
Green Bee-eater	C	C	C	C	F	F	F	F	C	C	C	C
Pied Kingfisher	F	F	F	F	F	F	F	F	F	F	F	F
Small Blue Kingfisher	F	F	F	F	F	F	F	F	F	F	F	F
White-breasted Kingfisher	F	F	F	F	F	F	F	F	F	F	F	F
Yellow Wagtail	C	C	C	C	F	F	F	F	VC	VC	VC	VC

Table 3

Distribution of more Numerous Birds along the MulaA-Mutha, January 1983.

River-course between :	(1)															
	Vitthalwadi				Pumping Station				Dattawadi Br.				Garware Causeway			
	Ja	Fe	Ma	Ap	Ja	Fe	Ma	Ap	Ja	Fe	Ma	Ap	Ja	Fe	Ma	Ap
Egrets	C	F	F	F	F	C	C	VC	C	C	VC	VC	C	C	VC	VC
Pond Herons	F	F	F	F	F	C	C	VC	F	C	C	C	F	C	C	C
Dabchik	F	F	-	-	F	F	C	C	C	VC	VC	C	C	F	C	VC
Blackwinged Stilt	F	F	F	F	F	C	C	C	A	A	A	VC	A	A	A	A
Gull-billed Tern	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F

River-course around :	(2)											
	Sambhaji Br.				Omkareshwar				Shivaji Br.			
	la	Fe	Ma	Ap	la	Fe	Ma	Ap	Ja	Fe	Ma	Ap
Egrets	VC	C	VC	C	C	C	C	C	F	F	F	F
Pond Herons	C	C	C	C	C	C	C	C	F	F	F	F
Dabchik	F	F	-	-	C	C	C	C	F	F	F	F
Blackwinged Stilt	VC	A	VC	C	C	A	C	C	F	F	-	-
Gull-billed Tern	F	-	-	-	F	F	-	-	F	F	F	-

River-course around :	(3)											
	Dengle Br.				Sangam Br.				Bird Sanctuary			
	Ja	Fe	Ma	Ap	Ja	Fe	Ma	Ap	Ja	Fe	Ma	Ap
Bird-Species	C	C	C	C	C	VC	VC	C	A	A	A	A
Pond Herons	C	C	C	C	C	C	C	C	VC	VC	VC	VC
Dabchik	C	C	VC	C	VC	VC	C	C	A	A	A	C
Blackwinged Stilt	F	F	F	F	F	F	F	F	C	A	A	A
Gull-billed Tern	C	C	F	F	C	C	F	F	C	A	VC	C

Explanation : Table Nos. 2 and 3.

F	Bird no.s between 1 and 10, i.e. Few	Ja	January
C	Bird no.s between 11 and 30 i.e. Common	Fe	February
VC	Bird no.s between 31 and 70 i.e. Very Common	Ma	March
A	Bird no.s between 71 and above i.e. Abundant	Ap	April

of birds were recorded on the rivers. Their distribution according to habitat was :

Deep-water Habitat : 6
Shallow-water Habitat : 9
Marshland Habitat : 16
Dryland and Rocky Habitats : 24
Riverside Trees : 5
Birds in flight : 11

On any one day an average of 37 species were noted on the river Mutha during this period, with a total number of 1806 individuals. In this stretch of about 6.5 km this number gives an average density of 277 birds per kilometer. This number does not include arboreal birds seen on trees by the riverside. In the Bird Sanctuary on an average 1490 individuals belonging to 42 species were recorded on the days of counts. This 1.5 km stretch thus gives a density of 993 birds per kilometer.

As will be seen from Fig. 1 there are some definite places where birds were seen to congregate. These three places according to the number of birds found there, are: 1. The stretch between the Pumping Station and Dattawadi Bridge, 2. The stretch between this bridge and Garware College causeway, 3. The stretch

between the broken causeway behind PMT bus terminus and Omkareshwar temple. Fig. 3 shows the distribution of birds in the Bird Sanctuary.

Fig. 2 shows birds at different places along the river Mutha according to three broad habitat types. As will be seen from the figure, the number of birds seen along the edges of the river was the highest followed by the number seen in deepish water. The number of species seen along the edges was 15 while those seen in deepish water was 7. Some of the species like Blackwinged Stilt were common to both these habitats.

In the Bird Sanctuary (Fig. 4) the number of species seen along the edges was 17 while in deepish water the number was 12. While counting these numbers such species as House and Jungle Crow, Common Myna, Pariah Kite and Little Brown Dove which are not strictly river-birds are excluded. In the bird count taken in March 1979, in the Bird Sanctuary, 39 species had been recorded with a total number of about 1200 individuals (P. Gole 1980).

The quality of water where birds were seen to concentrate, was also examined. As has been pointed out in the section on water-quality, the river takes on an increasing load of organic pollution as it flows from Vitthalwadi onwards.

It will now be interesting to see if any change in the composition of bird species in different months on the stretches where birds concentrated, can be detected. Table No. 2 gives this information. The table shows that in the first two stretches the numbers of egrets, stilts, dabchiks, and Gullbilled terns are low; while these birds become more numerous from Garware College causeway to Omkareshwar temple. We have recorded in greater detail the distribution of these species between January and April. Table No. 3 shows their distribution along the entire river course. From this it is clear that these birds are fewer where the quality of water is better and drains do not overflow into the river. Their numbers progressively increase as the quality of water deteriorates and its organic content goes up. It appears that these birds have adopted the role of scavengers along the river course. Special mention should be made of Blackwinged Stilt. These were found to be concentrated, at places in very large numbers, where streams loaded with faecal matter and drains flow into the river. To a lesser extent this can be said to be true of the three species of egrets also. Gullbilled terns were also seen to patronize such places in numbers and to swoop repeatedly to pick up floating organisms.

As the summer advances and April gives way to May, most of the migratory birds including the hordes of Blackwinged Stilt which make the dirty river so colourful, will have left. June and July would see even the egrets disappearing from the river. With the monsoon in full swing, floods roar down the river channel and the turbulent stream appears to cleanse itself of all the dirt that man continues to heap on it.

Acknowledgements

The study formed a part of the much wider investigation aimed at drafting an eco-development plan for the improvement of Pune's river-fronts. This wider study was financed by the Ecological Society of Pune. I was helped in the field by Miss S. Limaye, Miss S. Ranjekar and Miss S. Jangam. The water-samples were analysed by Shri Kirad of Kirloskar Consults Ltd. and Dr. Godbole of Vidnyan-vardini. Botanical specimens were identified by Dr. Vartak of Vidnyan-vardhini and Miss Sane of Garware College. I thank all these persons.

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Flood Pulsing in Restoration : A Feasible Alternative for India?

Beth Middleton

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Abstract

The full restoration of natural flood pulsed conditions has only been attempted in a few places in the world because the politics behind the original destruction of the wetland generally impedes full restoration. Often the desire to restore wetlands for wildlife and other purposes is not strong enough to alter or eliminate the engineering projects such as embankment, diversion, interbasin water transfer and hydroelectric dams for water, irrigation and electricity that destroyed the original wetland. Unfortunately, we must find ways to provide plant and animal species flood pulsed habitats because many of these are not only adapted to, but dependent on this environment for their continued survival.

The restoration of flood pulsing has been accomplished only in a handful of places such as the Kissimmee River (Florida U.S.A.) and the Lodi Wildlife Area (Wisconsin U.S.A.). At the same time, many partial restorations have been successful removing or working with engineering projects. After the floods of the Mississippi River (U.S.A.), many people moved off the flood plain with the blessing of the Federal Emergency Management Agency. Now, several embankments (levees or bunds) have been removed, and areas are reverting to natural vegetation. Downstream from hydroelectric dams in the Cameroon (Africa) and near Pune (India), impounded borrow areas with bunds have created fisheries/vegetable gardens and wildlife habitat, respectively. Restoration of spring habitats in arid and montane regions can be as simple as removing cattle from the banks of streams as in the case of the "Magic Spring" near Cartago (Costa Rica). The inclusion of flood pulsing in riverine restoration in India is a new idea as it is everywhere, but we must give serious consideration to recreating the original conditions of the habitat for the benefit of the animals and plants that utilize these wetlands.

The Engineering of Rivers Worldwide

Complete restoration of floodplain wetlands must reestablish overflow flooding from river and stream channels across the floodplain (floodpulsing) during the rainy season of the year (Middleton 1999). Because most of the world's rivers have been reengineered by dams, embankment via levees or bunds, channelization, and/or diversion (Gregory 1977), often the conditions created by engineering projects need to be reversed before successful restoration can occur. However, the dried floodplains created by these engineering projects can make capital investment possible (Pearce 1991), so that, reversing these conditions may be politically impossible. Nonetheless, wetlands are very important to humans. Settlements in India are often directly adjacent to wetlands attesting to their importance for washing, bathing, drinking, livestock and irrigation (Figure 1) (Foote *et al*. 1996).

Embankments (levees, bunds) are designed to cutoff the transfer of water between the channel and the floodplain (Middleton 1999) and have been constructed worldwide to force the river into the channel and away from floodplains, e.g., along the Mississippi in the midwestern United States, Danube in Central Europe (Cowell 1997) and the Brahmaputra/Ganges/Meghna Rivers in Bangladesh (Brammer 1990a). While such reengineering allows humans to encroach the floodplain, it has serious consequences for the plants and animals that live on the floodplain that depend on the flood pulse for their growth and reproductive activities (Middleton 1999). Embankments impair the

ability of fish to spawn and rear young on flood plains and so can be a serious economic problem in countries such as Bangladesh where 80% of the protein consumed comes from fish (Sklar 1993).

Embankments are dangerous to the humans living behind them since they pose the very real threat of bursting during floods (Middleton 1999). While embankments may protect settlements and farmland from flooding in small flood events, these cause downstream flooding by forcing water away from upstream flood plains (Leopold and Maddock 1954). Over time, embanked farmland develops a lower elevation than the river channel because it does not receive enriching sedimentation from the river as is the case along portions of the Mississippi River (U.S.) and three Chinese rivers (Brammer 1990a). Floods improve soil nutrient levels; agricultural production usually increases the year after a flood, because of the enriching action of flood waters (Brammer 1990b; Rogers *et al*. 1989).

Breaches in embankments create opportunities for partial wetland restoration on floodplains for the benefit of vegetation, waterfowl and wildlife (Trepagnier *et al*. 1995). After the floods of 1993-94 along the Mississippi River in which the majority of embankments burst along the river near St. Louis, MO, some of the embankments were not replaced because it was realized that the river had been constrained too far. Entire villages of peoples moved off of the floodplain after this major flood with the encouragement of the Federal Emergency Management Agency (U.S.) (Middleton 1999). In areas designated for flood retention along the American Bottom near St. Louis, embankments were removed or moved back from the Mississippi River. Natural vegetation reestablished in those places spontaneously from seed bank and seed dispersal processes but it did not resemble its original composition (Giedeman 1999).

Stream Diversion and InterBasin Water Transfers

The diversion of water away from a river for irrigation or drinking water obviously has a big effect on the volume of water involved in the flood pulse on the floodplains of rivers and thus has huge consequences for the biota along the river. Irrigation projects are common in arid lands and India has irrigation canals that have been operational for hundreds of years (Ali 1982). However, the consequences of these activities have been little considered from the perspective of wetland conservation and restoration.

Any engineering project that transfers water from previously unconnected water bodies creates a new corridor for the flow of water and biota. Such interbasin water transfers curtails the transfer of genetic material along the original corridor, and creates a

Village in northern India dependent on a local wetland (photo by Beth Middleton)

new avenue of genetic transfer where none existed before. Other threats along these altered corridors include the invasion of new species of animals and plants, change of water quality and the spread of disease vectors (Davies *et al*. 1992).

Dams

Many significant rivers have been dammed in India (World Wide Fund for Nature India 1993) and some of these dams are thought to have been built as early as 3150 BC (National Committee for Geography 1968). While dams to create rice paddies and fish ponds create wetlands, these also destroy wetlands by diverting water from downstream areas (Foote *et al*. 1996). Large dams in particular threaten humans. Dams sometimes burst and cause human death and destruction, not to mention the thousands of people that are displaced by the construction of dams in the first place (Costa 1988).

Everywhere in the world, dams change biological processes both up and downstream regarding water flow, sedimentation, nutrient cycling and energy exchange (Sparks *et al*. 1990). Upstream from dams, sites become permanently impounded with little water fluctuation. Downstream, water is often reduced to a trickle. Worse yet for the biota, the operations of a hydroelectric dam, water is released suddenly and during inappropriate seasons of the year. This has severe consequences for those biota that are unable to adapt to these sudden extremes in water and sediment conditions (Middleton 1999). Dam building began along the Chambal River in the 1960s, and subsequently, crocodile number dropped because these could not adapt to the changes in the waterway (Sharma and Singh 1986)

Though an attractive idea, dam removal has not been uniformly successful in restoring wetlands. One big problem is that sediments build-up behind dams, and opening them allows a sediment plume to move downstream (Simons 1991). Sediments behind the dams can be difficult to revegetate (Shuman 1995). In certain cases, the sediments behind dams have toxins (e.g., PCB) and thus are an environmental hazard (Shuman 1995; Tofflemire 1986). Controlled releases of water from dams show some promise for simulating flood pulses and this has been tried with some success in the Grand Canyon of the U.S. since 1996 (Stevens 1997).

Restoration in a Water Regulated World

Effective restoration needs to be accomplished at the landscape level. Paradoxically, the procedures used to destroy wetlands were typically accomplished at that level. To undo these problems, we need to rethink our approaches on the same large scale (McCorvie and Lant 1993). There are only a few examples of rivers or streams being restored on a landscape level in an attempt to put them back into their original condition and those include the Kissimmee River project (Florida, U.S.A.) and the Lodi Wildlife Area Project (Wisconsin, U.S.A.) (Middleton 1999).

Why should we attempt to create the original conditions in wetland restoration with flood pulsed conditions? Restoration attempts that have not attempted to recreate the original conditions have not been very successful. While wetland restoration has been practiced for at least 30 years in the United States, many of these have been deemed failures because of hydrological problems. While little study exists of their success, in one study based mostly in Florida (USA), less than 63% of the wetland restorations were successful (Erwin 1991).

The key to restoration is to provide species with the environment to which they are adapted. The life history of some species are so closely tied to a flood pulsed environment, that these cannot survive without it. Most plant species germinate and their seedlings only thrive in drawdown conditions (Middleton 1999). Not surprisingly, species of monsoonal wetlands are closely adapted to annual drawdown stemming from the yearly drought (Finlayson 1991; Middleton 1999; Middleton *et al*. 1991). In the Amazon, a millipede species (*Cutervodemus adisi* Golovatch) spends the flood season on tree trunks, and reproduces only on the drawdown forest flood (Adis *et al*. 1996). In cases where life history is very closely adapted to the flood pulsed environment, if that environment is altered by human engineering projects, the species will not survive (Middleton 1999).

Admittedly, natural flood pulsing on the flood plain is sometimes unacceptable for purely political reasons. If the goal in a region is to use all or even part of the flood plain for housing, agriculture or other human purposes, it is essential to control unpredictable flooding on the flood plain. However, the reality is that people cannot be completely protected with either embankments or dams for the purpose of holding back the water during floods. The devastating and recurring floods along floodplains of the Mississippi River (Mississippi River Corridor Study Commission 1995), the Danube in Europe (Cowell 1997) and Brahmaputra/Ganges/Meghna Rivers in Bangladesh (Brammer 1990) have taught us that we can not control rivers all the time.

There are some very successful projects that partially restore flood pulsing along rivers. The Project Pisciculture Lagdo has maximized water for fisheries and vegetable farming along a dried floodplain downstream from the Lagdo Reservoir along the Benue River in Cameroon (Slootweg and van Schooten 1995). In addition to creating wetlands downstream from the hydroelectric plant, the project also helped to compensate fishermen for the loss of their resource after the dam was put in place.

The Ecological Society of India has created borrow areas with small bunds to impound water below the Panshet Dam near Pune, India. The project has created wildlife habitat for a large variety of birds, fish and amphibians (Middleton 1999). In upland areas of the same watershed, the hillsides were stripped of vegetation. Natural revegetation occurred and created habitat for a wide variety of wildlife after cattle were excluded (Gole 1990).

Other wetland restoration projects have only been successful after cattle have been excluded, particularly in arid and/or montane situations. In Costa Rica, one mountain stream dried up because of cattle grazing near Cartago, Costa Rica in the Vulcán Irazú watershed. After the cattle were removed, water flow returned to this stream. The "Magic Spring" that had been sacred to the indigenous tribal people there, reappeared as a permanent water body (Don Angel Rodriguez and Margarita Boloños, personal communication).

It would seem that either full or partial wetland restoration projects have been accomplished throughout the world. The benefits of wetland restoration are clear for the preservation of the world's threatened biota, but at the same time can be equally beneficial for humans. All flood plains cannot be made completely safe from dangerous floods, and certainly some of these can be put to better use as wetland habitats. In addition, engineering projects can be made to accommodate the needs of people and wildlife to a greater extent than they have in the past. These approaches all present opportunities for wetland restoration in India and other parts of the world.

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Animal Agriculture is the Leading Cause of Climate Change – A Position Paper

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Abstract

In this paper, we present the results of a Global Sensitivity Analysis (GSA) proving that Animal Agriculture is the leading cause of climate change, responsible for 87% of greenhouse gas emissions. The burning of fossil fuels is currently the leading source of human-made carbon dioxide (CO2) emissions. However, climate change is caused by cumulative human-made greenhouse gas and aerosol emissions and not just current CO2 emissions alone. While humans have been burning fossil fuels for a little over 200 years, we have been burning down forests for Animal Agriculture for well over 8,000 years! For the GSA analysis, we use factual data from the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) and other peer-reviewed scientific sources. We show that we need to transition to a global plantbased economy first and that blindly eliminating fossil fuel usage first will accelerate the warming of the planet. We show that the annual methane emissions from Animal Agriculture alone causes more incremental global warming than the annual CO2 emissions from all fossil fuel sources combined. We further show that the transition to a global plant-based economy has the potential to sequester over 2000 Giga tons (Gt) of CO2 in regenerating soils and vegetation, returning atmospheric greenhouse gas levels to the "safe zone" of under 350 parts per million (ppm) of CO2 equivalent, while restoring the biodiversity of the planet and healing its climate. This paper clearly illustrates why the scientific community, government institutions, corporations and news media, who vastly underestimate the role of Animal Agriculture and focus primarily on reducing fossil fuel use, need to urgently change their priorities in order to be effective.

1. Introduction

The burning of fossil fuels is undoubtedly the leading source of human-made Carbon DiOxide (CO2) emissions today. CO2 is the most powerful human-made greenhouse gas in terms of its radiative forcing, which is the average energy trapped by the greenhouse gas per unit time per unit area of the Earth's surface, typically measured relative to the base year 1750. In the absence of active reforestation efforts, CO2 is a long-lived greenhouse gas as it persists in the atmosphere for tens of thousands of years. The Fifth Assessment Report (AR5)[1] of the Intergovernmental Panel on Climate Change (IPCC) estimates the mean radiative forcing of human-made CO2 to be 1.68 Watts/square meter (W/m2). The next most powerful humanmade greenhouse gas, methane, with a mean radiative forcing of 0.97 W/m2, lingers in the atmosphere for an average of 10-12 years before it reacts with oxygen free radicals and also converts into CO2. As such, it is tempting to conclude that a single-minded focus on the reduction of fossil fuel burning to minimize future human-made CO2 emissions is the best strategy to address climate change. Indeed, the global scientific community, government institutions, corporations and news media have adopted this strategy without much questioning. They have also unquestioningly accepted the United Nations (UN) Food and Agricultural Organization (FAO)'s estimate)[2] that the lifecycle emissions of the Animal Agriculture industry sector is a

mere 14.5% of global human-made greenhouse gas emissions, which justifies their urgency of reducing fossil fuel burning over dealing with the Animal Agriculture sector.

In this paper, we will show that this strategy of focusing exclusively on the reduction of fossil fuel burning will accelerate climate change, potentially to the point of no return. Using a Global Sensitivity Analysis (GSA) method, we will show that the UN FAO's 14.5% estimate for the lifecycle emissions of Animal Agriculture is incorrect and that the correct estimate is at least 51% as calculated by Goodland and Anhang[3] and this lower bound can be tightened to at least 87% of global greenhouse gas emissions. Therefore, Animal Agriculture is the leading cause of climate change.

Furthermore, we will show that a global transition to a plant-based economy has the potential to sequester over 2000 Giga tons (Gt) of CO2 in regenerating soils and vegetation, returning atmospheric greenhouse gas levels to the "safe zone" of under 350 parts per million (ppm) of CO2 equivalent (CO2e), while restoring the biodiversity of the planet and healing its climate.

The organization of this paper is as follows :

In Section 2, we will examine how waste "exhaust" from human activities changes the Earth's climate. The exhaust can be classified as either greenhouse gases, which heat up the Earth's atmosphere or aerosols, which are atmospheric particles that generally cool the Earth's atmosphere. The main human-made greenhouse gases are CO2 and methane, which are both carbon-based gases and the main human-made aerosols are sulphates, which are primarily produced when we burn coal and oil.

In Section 3, we will examine how the carbon cycle of the planet has been impacted by two main human activities over the past 8,000 years : land clearing or land use change, primarily for agriculture, and fossil fuel burning.

In Section 4, we will examine current agricultural land use and biomass flows to establish that Animal Agriculture is the primary sector necessitating land clearing, causing climate change. Next, we will compare Local Sensitivity Analysis (LSA) vs. Global Sensitivity Analysis (GSA) on the two main human activities causing climate change : Animal Agriculture and fossil fuel burning. While the LSA is useful for determining the impact of local variations in the current emissions scenario, it can lead to inaccurate results when extrapolated out on a global scale. In contrast, the GSA is based on analyzing a global change directly and will lead to more accurate results for that change. Using the GSA method, we will reveal the inaccuracies in the UN FAO's 14.5% estimate on the greenhouse gas emissions contribution of the Animal Agriculture sector. Next, we will show that the Goodland-Anhang estimate of 51% is truly just a lower bound on the greenhouse gas emissions contribution of the Animal Agriculture sector. We will then tighten this lower bound using the Carbon Opportunity Cost (COC) estimates of Searchinger et. al. and show that the correct estimate for the greenhouse gas emissions contribution of Animal Agriculture is at least 87%[4].

In Section 5, we will estimate the CO2 sequestration potential and the resultant climate mitigation that can occur with the global transition to a plant-based economy.

Finally, we have included an Appendix detailing the four major miscalculations in the IPCC reports, which systematically undercount the climate change impact of Animal Agriculture.

In what follows, for the sake of simplicity, we have used the specified statistical mean or the midpoint of uncertainty ranges in the data found in the IPCC reports and other peer-reviewed sources. Our conclusions do not change if we include the underlying uncertainty ranges and other nuances, but we will likely lose clarity in our presentation.

2. How Humans Change Climate

Almost everything humans do changes the Earth's climate. The waste "exhaust" from human activities can either heat up the Earth or cool it. Therefore, the question is not whether humans change the Earth's climate, but how much and in what direction. When billions of humans drive cars, burn coal and natural gas for electricity and consume animal products, the exhaust gases and particles from these activities heat or cool the Earth. Exhaust gases such as CO2, methane and nitrous oxide (N2O) heat the Earth. Exhaust particles such as sulphates and nitrates cool the Earth. Other exhaust particles, such as black carbon, heat the Earth.

The UN IPCC has quantified the impact of each of these exhaust gases and particles in terms of radiative forcing measured relative to their levels that existed in the year 1750 as the base year (see FIg. 2.1)[1]. CO2 is the main human-made exhaust gas that heats the Earth and it is estimated to provide an additional 1.68 W/m2 of heating power relative to its atmospheric concentration in 1750. In other words, the impact of the additional CO2 in the atmosphere since 1750 is like adding a 1.68 Watt continuous heater on every square meter of the Earth's surface.

The next most significant human-made exhaust gas is methane, which has the chemical formula CH4. Methane is estimated to have a mean radiative forcing of 0.97 W/m2 and it lingers in the atmosphere for an average of 10-12 years before it reacts with oxygen free radicals and also converts into CO2. The number one cause of methane emissions is Animal Agriculture, which contributes 37% of it[2]. Even though the radiative forcing of methane (0.97 W/m2) is less than that of CO2 (1.68 W/m2), the annual emissions of methane has a more significant impact on net radiative forcing, and therefore climate change, than the annual emissions of CO2.

The annual emissions of methane from 2011-2016 was 0.363 Gt, on average[6].

The amount of methane added to the atmosphere since 1750 until 2011 is 1.1ppm, which corresponds to 3.12 Gt of methane[27].

Therefore, to a first order approximation, our annual emissions of methane is contributing 0.97x0.363/3.12 = 0.11 W/m2 of radiative forcing.

In contrast, the annual emissions of CO2 from 2011 to 2016 was 39 Gt, on average[6].

The amount of CO2 added to the atmosphere since 1750 until 2011 is 110ppm, which corresponds to 859 Gt of CO2[27].

Therefore, to a first order approximation, our annual emissions of CO2 is contributing 1.68x39/859 = 0.076 W/m2 of radiative forcing.

Since just 45% of the annual CO2 emissions remains airborne due to uptake from land and the ocean, the additional radiative forcing from our annual CO2 emissions is 0.45x0.076 = 0.034 W/m2, about one-third the methane contribution.

It is important to point out that the IPCC has consistently undercounted the impact of our annual methane emissions by averaging its impact over a 100 year period. Even as it warns humanity that catastrophic climate change is imminent within the next 11 years, not 100 years[7]!

In the latest report issued in August 2019[6], the IPCC is still using a Global Warming Potential (GWP) of 28 for converting methane emissions to a CO2 equivalent (CO2e). Global Warming Potential (GWP) converts the radiative forcing impact over a specified time horizon of a unit mass of gas, related to the reference gas, CO2. For methane, the GWP over a 100 year time horizon, excluding cloud effects, is 28. The GWP of methane over a 10 year time horizon, including cloud effects, is 130[10].

If we used GWP of 130 for methane, then the annual emissions of methane would be 0.363X130 = 46.9 Gt CO2e, which exceeds the annual emissions of CO2 (39 Gt CO2).

Since just 45% of the annual CO2 emissions remains airborne each year, the comparison of methane (46.9 Gt CO2e) should be with respect to 0.45 X 39 = 17.6 Gt CO2.

Therefore, the climate change impact of our annual CO2 emissions (17.6 Gt CO2) is about onethird the impact of our annual methane emissions (46.9 Gt CO2e), just as we calculated above.

Indeed, the impact of methane from Animal Agriculture alone is 37% of 46.9 Gt CO2e, which works out to 17.3 Gt CO2e.

This exceeds the impact of all fossil fuel based CO2 emissions, which is 87% of 17.6 Gt Co2, which works out to 15.3 Gt CO2.

For reference, please see Table on Page 9 of the latest IPCC report[6].

The third most significant human-made exhaust particles are sulphate aerosols, created mainly during the burning of coal and oil. According to NASA, "the sulfate aerosols absorb no sunlight but they reflect it, thereby reducing the amount of sunlight reaching the Earth's surface. Sulfate aerosols are believed to survive in the atmosphere for about 3-5 days.

The sulfate aerosols also enter clouds where they cause the number of cloud droplets to increase but make the droplet sizes smaller. The net effect is to make the clouds reflect more sunlight than they would without the presence of the sulfate aerosols. Pollution from the stacks of ships at sea has been seen to modify the low-lying clouds above them. These changes in the cloud droplets, due to the sulfate aerosols from the ships, have been seen in pictures from weather satellites as a track through a layer of clouds. In addition to making the clouds more reflective, it is also believed that the additional aerosols cause polluted clouds to last longer and reflect more sunlight than non-polluted clouds."

The radiative cooling effect of human-made sulphate aerosols together with their cloud adjustments is estimated to be -0.95 W/m2.

The fourth most significant human-made exhaust are black carbon particles, which cause a radiative heating effect of 0.6 W/m2. These are formed due to the incomplete combustion of fossil fuels, biofuels and biomass. The main emissions sources are diesel engines, wood burning cookstoves and forest fires that humans ignite to clear land for Animal Agriculture and other sundry purposes. Fig 2.2 shows a map of the world depicting forest fires seen from space by the NASA MODIS Satellite during a 10 day period in May

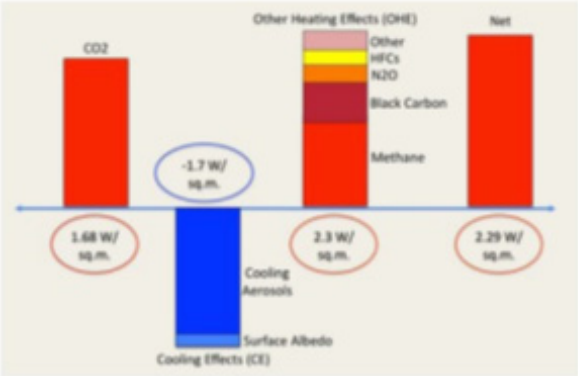

Fig. 2.1. Anthropogenic Radiative Forcing from various greenhouse gases and aerosols, broken into three grouped segments: 1) CO2, 2) Cooling effects such as sulphate aerosols and changes in surface albedo and 3) Other Heating Effects such as methane, Black Carbon, Nitrous Oxide, Halocarbons, etc. Values sourced from IPCC AR5 WG1 Chapter 8.

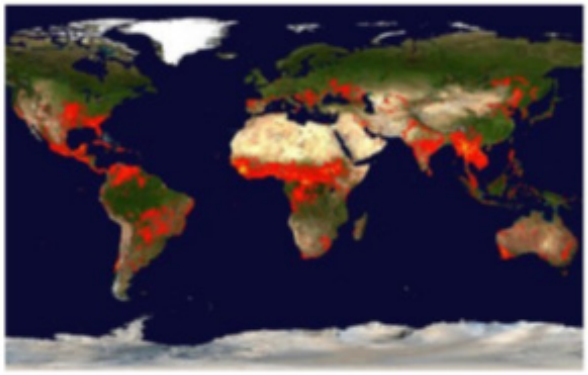

Fig 2.2 NASA MODIS Satellite map of fires that occurred in a 10-day period in May 2019. Most of the fires are human caused, primarily to clear land for Animal Agriculture.

of 2019! Such forest fires are a significant source of black carbon emissions.

CO2 is absorbed by trees and plants during photosynthesis and it is stored away permanently in vegetation and soil in regenerating forests. However, in the absence of active reforestation efforts, CO2 is a long-lived greenhouse gas that lingers in the atmosphere for tens of thousands of years. At present, about 85% of human-made CO2 emissions are from burning fossil fuels, i.e., coal, oil and natural gas. The remaining 15% is mainly from burning down forests to clear land, i.e., land-use changes[8].

However, since CO2 is a long-lived greenhouse gas, it is the cumulative emissions of CO2 over time that impacts its radiative forcing, not current emissions alone. In 1850, land use changes were the main source of human-made CO2 emissions, while at present, it is fossil fuels (see Fig. 2.3). Integrating the annual CO2 emissions components over time, we see in Fig. 2.4 that between 1850 and 2011, cumulative CO2 emissions due to land use changes is second only to that from coal burning. Besides, land use changes have been occurring for over 8,000 years, whereas fossil fuel burning only started in the industrial era, around 200 years ago. Since the long-range time constant of CO2 rock weathering sequestration is on the order of tens of thousands of years, it is relevant to consider the cumulative CO2 emissions from land use changes over the past 8000 years. Kaplan et al. has estimated the CO2 emissions due to land use changes in the pre-indus-

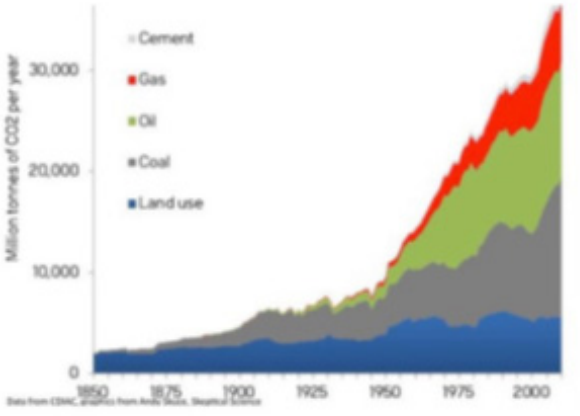

Fig. 2.3. Annual anthropogenic CO2 emissions from Land Use Change + Coal + Oil + Gas + Cement production. Please note that the Land Use Change component dominated in 1850 while the fossil fuel components dominate at present

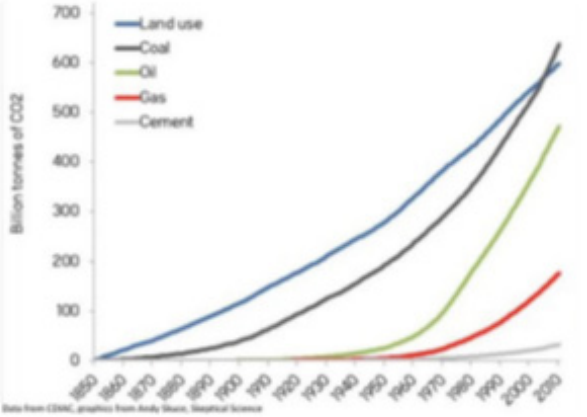

Fig. 2.4. Cumulative CO2 emissions from Land Use Change, Coal, Oil, Gas and Cement production from 1850 onward. Kaplan et. al. estimate the Land Use Change contribution prior to 1850 to be 343GtC or 1260 Gt CO2.

trial era to be 1250 Gt CO2[9]. This implies that if we integrate from 8000 years ago to 2011, CO2 emissions from land-use changes (1850 Gt CO2) exceeds the CO2 emissions from all fossil fuel sources combined (1200 Gt CO2). Therefore, land use changes are the leading cause of human-made CO2 emissions over the years and not fossil fuel burning.

In summary, of the four main human-made exhaust gases and particles impacting climate change,

1) Land use changes, primarily for Agriculture, is the leading cause of CO2 emissions, a global heating component with the largest radiative forcing;

2) Animal Agriculture is the leading cause of methane emissions, the global heating component contributing the most incremental heating on an annual basis;

3) Fossil fuel burning is the leading cause of sulphate emissions, a global cooling component; and

4) Animal Agriculture is a leading cause of black carbon emissions, a global heating component.

With the lone exception of sulphate aerosols, which are mainly a byproduct of fossil fuel combustion, the other three main exhaust gases and particles causing climate change - CO2, methane and black carbon - are molecular forms of carbon. Therefore, let us now take a closer look at how humans have altered the carbon composition of the planet.

3. How Humans Changed Carbon

Carbon is stored on land in vegetation and soils. Roughly half the weight of a tree is carbon. Half the weight of a tree is below ground and half above ground and therefore, the above ground weight of a tree is a good measure of the amount of carbon stored by the tree. In general, soil contains three times as much carbon as the vegetation it holds. Soil carbon excludes carbon stored in trees, plants, animals, birds and insects.

Carbon is stored deep underground in the form of fossil fuels. It is also stored under permafrost land in the form of ancient vegetation that got frozen and preserved at the dawn of the ice ages 3 million years ago.

Carbon is stored in the ocean in surface, intermediate and deep sea sediments. It is also stored in the ocean as dissolved carbon. Finally, carbon is found in the atmosphere, primarily as CO2, methane, organic carbon and black carbon.

For at least 8000 years, humans have been displacing carbon by clearing land for agriculture and by burning fossil fuels (see Fig. 3.1). Most of that displaced carbon has returned back to land, while some has dissolved into the ocean and 240 GtC of it has remained in the atmosphere in the form of greenhouse gases causing climate change. It is estimated that in the pre-industrial era, humans displaced around 300 GtC of carbon on land, but this barely made a dent in the atmospheric CO2 levels as most of it returned back to land in the form of Arctic peat moss, which is a large absorbent moss that grew in the Arctic tundra on boggy ground. Since then, humans have combusted 365 GtC of carbon from the planet's fossil reserves and displaced 164 GtC from vegetation and soil on land. Of that total of 529 GtC of carbon, 45% or 240 GtC has remained airborne in the form of CO2, methane, etc., in the atmosphere, while 155 GtC has dissolved into the ocean and 134 GtC has returned back to land[11].

Humans have cut down about 46% of the trees on land since the dawn of civilization[12]. This corresponds to displacing an estimated 464 GtC from vegetation and soils and sending it up into the air. While

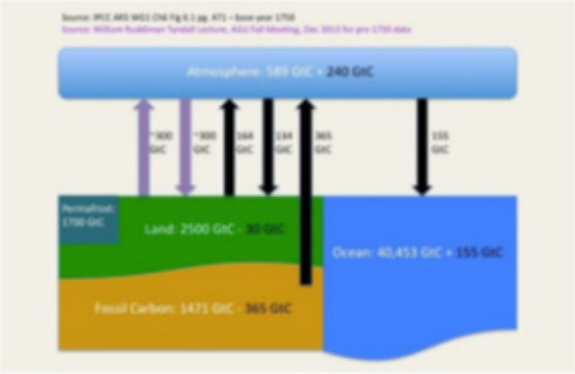

Fig. 3.1. Carbon storage in permafrost, land, ocean, fossil reserves and the atmosphere in 1750 (in white) and the changes since then due to human activities.

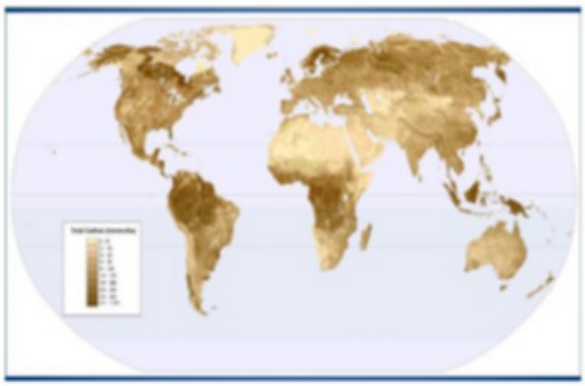

Fig. 3.2. The distribution of carbon on land is highly uneven. The density of carbon is highest in forests and lowest in grazing lands and deserts.

the pre-industrial clearing of land was compensated by carbon storage in Arctic peat moss, the industrial-era clearing has been mostly compensated with additional storage in forests due to the so-called CO2 fertilization effect[13]. Since the land clearing in the industrial era was accompanied by fossil fuel burning, it raised the atmospheric CO2 levels, which spurred plant-growth due to more efficient photosynthesis. Therefore, even though the cleared land is storing very little carbon as we shall see below, the remaining forests now have a greater density of carbon than in pre-industrial times, which partially offsets the carbon lost due to land clearing.

At present, 2470 GtC is stored in 130 Million square kilometers (MKm2) of the ice-free land area of the planet, for an average carbon storage density of 19,000 tons per sq. km (t/Km2). According to the IPCC Land Use Block diagram (see Fig. 11.9, page 836), 46 MKm2 or 35% of that land is used as grazing land for Animal Agriculture[14]. The Integrated Science Assessment Model (ISAM) at the University of Illinois estimates that this grazing land is currently storing 53 GtC, for an average of 1,150 t/Km2, or just 6% of the global average[15]. This is reflected in the global land carbon stock map of Fig 3.2, which shows vast swathes of the planet with low carbon density corresponding to where human and farmed animal population is dense.

4. Sensitivity Analysis for Human Activities Causing Climate Change

In the previous sections, we have established that land clearing, primarily for Agriculture, and fossil fuel burning are the two main human activities causing climate change. In this section, we will compare the climate change impact of eliminating fossil fuel burning with the impact of eliminating Animal Agriculture, a sub-sector of Agriculture.

At the dawn of the Agricultural revolution, 10,000 years ago, human biomass was negligible compared to the biomass of "megafauna", which are large wild animals that are greater than 44kg in average weight. At that time, humans could afford to lead a predatory existence, cooking and eating animal foods (see Fig. 4.1)[16]. However, in the industrial era, by 1970, human biomass alone was equal to the biomass of all megafauna from 10,000 years ago. In addition, humans were now farming animals whose total biomass was roughly double that of humans, but who were consuming three times as much food as all humans. As far as the planet was concerned, our farmed animals were presenting the profile of a biomass that was triple the biomass of all the megafauna from 10K years ago. Meanwhile, the biomass of megafauna had declined by 60%.

Fast forward another 40 years and by 2010, human biomass had doubled from 1970 levels. Our farmed animals were now eating 4.5 times as much food as all humans thereby presenting the profile of a biomass that is NINE times the biomass of all large wild animals from 10,000 years ago[14]. The biomass of wild animals had declined by 52% from 1970 levels and therefore down by 81% from 10K years ago[17]. The decline in the biomass of wild animals was also accelerating exponentially to be 58% from 1970 levels by 2012[18] and 60% by 2014[19]. The primary driver for this decline is human land clearing for agriculture, since 80% of mass extinction is due to habitat loss[20].

In terms of dry matter biomass, our "livestock" or farmed animals consume more than 80% of the food that we extract from the planet in order to provide just 15% of the food (including "seafood") that humans consume (see Fig. 4.2)[14]. Therefore, plant-based food comprises 85% of the food we eat, in terms of dry weight. Poore and Nemecek have calculated that plantbased foods provide 82% of the calories and 63% of the protein that we consume[21]. Therefore it is not too far-fetched to ask the question, how much can we mitigate climate change if we eliminated the Animal Agriculture sector altogether and relied entirely on plant-based foods and products? Indeed, this is a much more immediate, practical scenario than eliminating fossil fuel burning altogether. Of course, this would require us to not use animal products for any purpose whatsoever, i.e., to adopt a "vegan" lifestyle, since at present, the Animal Agriculture industry is providing 190 million tons of "food" for human consumption along with 140 million tons of "other raw materials" such as skin, blood and bones. If we only change our diets, but continue to purchase leather and other animal products, the industry is perfectly capable of raising animals just to produce the "other raw materials" and therefore, we may not be making much of a dent in our environmental impact.

In its Fifth Assessment Report, the UN IPCC had calculated that the "Agriculture, Forestry and Land Use" (AFOLU) sector was responsible for 12 Gt CO2e or 25% of the global greenhouse gas emissions by industry sector, including indirect emissions from the electricity and heat production sector (see Fig. 4.3)[1]. Since Animal Agriculture is a sub-sector under AFOLU, its contribution must be strictly less than 25%. In contrast, fossil fuel burning was calculated to produce 32 Gt of CO2 or 65% of the total greenhouse gas emissions (49 Gt CO2e) in 2010. Therefore it is tempt-

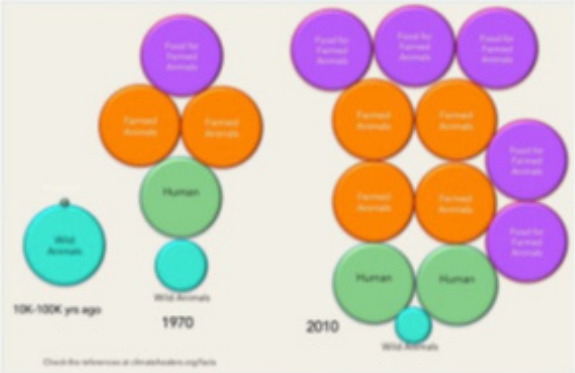

Fig. 4.1. The biomass of wild animals, humans and farmed animals over time. Human biomass was negligible compared to that of wild animals 10K years ago. Today, this biomass ratio is inverted and biomass levels are unsustainable.

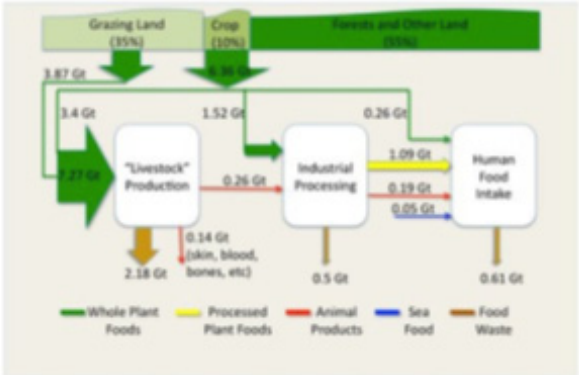

Fig. 4.2. Biomass flows, in Gigatons of dry matter biomass per year, through the Animal Agriculture sector, showing how "Livestock" are consuming 4.5 times as much food as all humans. Source IPCC AR5 WG3 Chapter 11, Fig 11.9, page 836.

ing to conclude that eliminating fossil fuel burning is a more effective climate mitigation strategy than eliminating the Animal Agriculture sector.

However, this is like inferring the Earth is flat based on local, line-of-sight observations. Such "Local Sensitivity Analysis" can be notoriously misleading. Firstly, the above comparison is based on current emissions and not on cumulative emissions or radiative forcing, which are more appropriate for measuring climate change impact. Secondly, the IPCC is using a 100 year time frame for calculating the CO2 equivalence of methane, which undercounts its more relevant 10-year impact by nearly a factor of 5. Thirdly, it is not just greenhouse gas emissions, but also aerosol cooling effects that need to be taken into account for comparing climate change impact. Fourthly, the IPCC is allocating each molecule of emission to one sector alone. Therefore, if a truck is transporting agricultural products, its emissions are being assigned to the transportation sector and not to the AFOLU sector. Finally, the UN IPCC is relying on the UN Food and Agricultural Organization (FAO) for its AFOLU data, while the FAO has publicly partnered with the International Meat Secretariat and the International Dairy Federation to promote intensive "livestock" farming (please see Appendix below for a detailed analysis of the IPCC's miscalculations). How reliable can the FAO's analysis be, when it is wedded to industry interests? Indeed, here's a timeline of events debunking the FAO's reports :

2005 - Alan Calverd published an estimate of GHG emissions from "Livestock" breathing alone is 8.8 Gt CO2e or 21% of total. "Livestock" breathing is a proxy for the avoided carbon sequestration while consuming animal products[22].

2006 – FAO published Livestock's Long Shadow (LLS) calculating lifecycle emissions from the "Livestock" sector to be 7.5 Gt CO2e or 18% of total, i.e., less than the breathing contribution alone[5]!

2009 – Goodland and Anhang published WorldWatch report correcting errors in LLS and calculating lifecycle emissions of the "Livestock" sector to be 32.6 Gt CO2e or 51% of total. This 32.6 Gt CO2e can be split into actual emissions of 21.1 Gt CO2e plus avoided carbon sequestration of 11.5 Gt CO2e (see Fig. 4.4) on the land that would be freed up when Animal Agriculture is eliminated[3]. The latter is their estimate of the "Carbon Opportunity Cost" of Animal Agriculture, to use the terminology of Searchinger et al. In the former, Goodland and Anhang used a 20-year timeframe for averaging the impact of methane instead of the 100 year timeframe used in the FAO's analysis[4].

2011 – FAO scientists published critique of Goodland and Anhang's estimate in Animal Feed Science and Technology (AFST) Journal[23].

2012 – Goodland and Anhang published refutation in AFST Journal and reiterated their estimate. FAO scientists declined to continue the debate despite AFST Editor's invitation[24].

2013 – FAO publicly partnered with International Meat Secretariat and the International Dairy Federation and published revision to LLS, calculating lifecycle emissions of the "Livestock" sector to be 7.1 Gt CO2e or 14.5% of total, without addressing any of the egregious errors pointed out in Goodland and Anhang's report or in the ensuing peer-reviewed debate[2].

Therefore, relying on the FAO's analysis is like relying on a Philip Morris scientific paper that extols

the cancer healing benefits of smoking Marlboro Lights[25]. In its lifecycle analysis of Animal Agriculture, the FAO had calculated the Carbon Opportunity Cost of Animal Agriculture, i.e., the carbon sequestration that will occur annually if the products of Animal Agriculture are replaced with plant-based alternatives, to be ZERO. This is blatantly incorrect, since Animal Agriculture is using 37% of the land area of the planet for just grazing alone and this grazing land is storing just 2% of the land carbon[2]. In addition, it appears that Goodland and Anhang may have also vastly undercounted the Carbon Opportunity Cost of Animal Agriculture since they only included CO2 stored in above ground vegetation and did not include CO2 stored in soil. Searchinger et al. calculate the Carbon Opportunity Cost to be an average of 5 tons of CO2 per person per year, which works out to a total of 34.5 Gt CO2 for a human population of 6.9 billion in 2010[4]. Therefore, the true Lifecycle emissions of Animal Agriculture is at least 55.6 Gt CO2e in 2010, i.e., 87% of the total.

In contrast to "Local Sensitivity Analysis," a "Global Sensitivity Analysis" works by considering the thought experiment: how will the human-caused radiative forcing change in the two scenarios :

a) Clean Energy Economy : if we eliminate fossil fuel burning and replace it with clean energy sources, keeping all else the same vs.

b) Plant Based Economy: if we eliminate the Animal Agriculture sector and replace it with plant-based sources, keeping all else the same?

In the Clean Energy Economy scenario, we assume that all energy sources have been transitioned to clean, zero emissions sources, but we will be continuing to burn down forests to grow more animal foods as before. Therefore, land use change emissions would continue to add CO2 to the atmosphere. The CO2 component of the radiative forcing would continue to increase but at a slower pace than before. Since we are no longer burning coal and oil, sulphate aerosols would disappear within 3-5 days, which means that the net radiative forcing would increase by 0.95 W/m2 due to this component. Finally, Other Heating Effects would remain the same so that the net radiative forcing would increase to 3.24 W/m2 from the present 2.29 W/m2, exacerbating numerous catastrophic climate feedback loops.

In the Plant Based Economy scenario, we assume that all animal products have been replaced with plant-based equivalents and that Animal Agriculture has been eliminated, but we continue to burn fossil fuels as necessary. From Fig. 4.2, we see that we can now supply all the plantbased food and product requirements from the cropland output alone, freeing up the grazing land for reforestation and carbon sequestration. This grazing land will begin sequestering 34.5 Gt CO2 per year, reducing CO2 levels in the atmosphere. In addition, a good chunk of the fossil fuel burning would disappear as we reduce our need for transporting vast amounts of food to animals, killing them in industrial settings, refrigerating their carcasses, treating diseased people, etc. About 40% of the methane in the atmosphere would disappear in 10-12 years, reducing the radiative forcing by 0.4 W/m2. The Black Carbon component of 0.6 W/m2 would reduce as we stop burning forests to create grazing land for animals. Therefore, we can expect the net radiative forcing to decrease to 1.3-1.7 W/m2 from the current 2.29 W/m2 within 10-12 years. As the net radiative forcing decreases, we can start gradually switching out

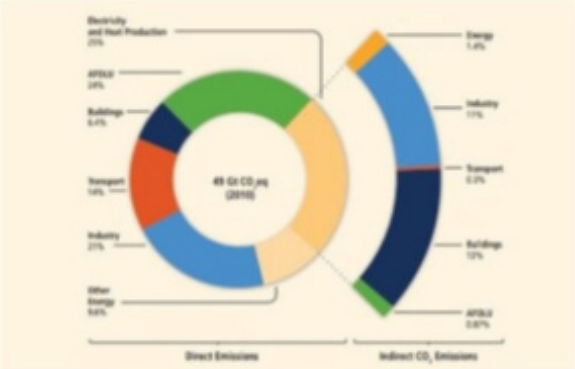

Fig. 4.3. Global emissions by economic sector according to the UN IPCC AR5. Agriculture, forestry and land use (AFOLU) comprise just 25% of the total, including indirect emissions from the electricity and heat production sector.

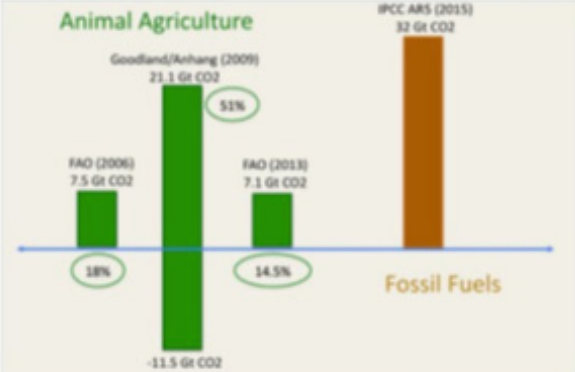

Fig. 4.4. Lifecycle emissions of Animal Agriculture as measured by the UN FAO (two versions) and World Bank scientists, Goodland and Anhang, in comparison with the total CO2 emissions from fossil fuel sources.

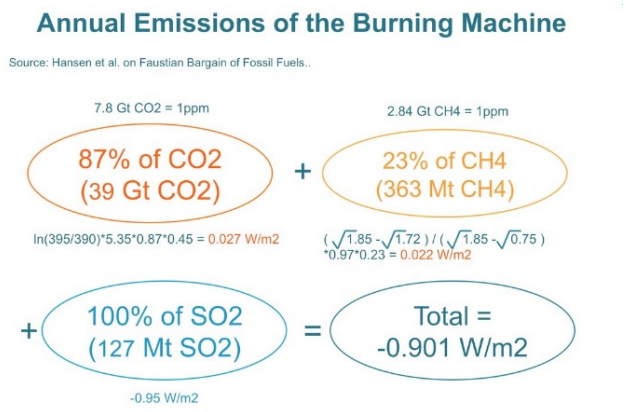

Fig 4.4a: Detailed calculations on the annual change in radiative forcing if the Burning machine is shut down, including CO_2, Methane and SO_2, while neglecting the impact of other minor greenhouse gases.

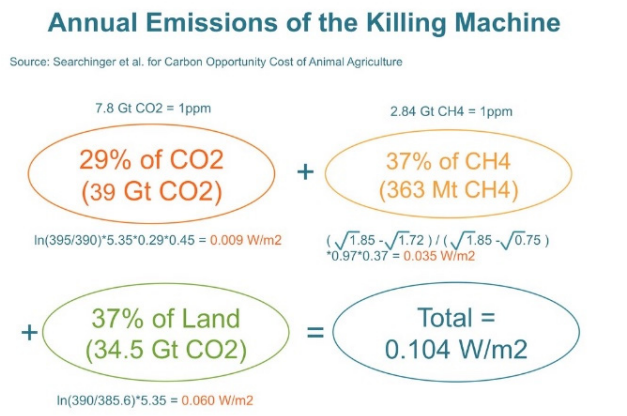

Fig 4.4b: Detailed calculations on the annual change in radiative forcing if the Killing machine is shut down, including CO_2, Methane and Land Use changes, while neglecting the impact of other minor greenhouse gases.

the fossil fuel infrastructure for clean energy sources without exacerbating catastrophic climate feedback loops.

The choice between these two scenarios should now be obvious. This shows that Animal Agriculture is indeed the leading cause of climate change.

5. CO2 Sequestration Potential in a Plant-Based Economy

At present, grazing lands store just 6% of the carbon per unit area when compared to the average for all land. In our Lifestyle Carbon Dividend poster paper

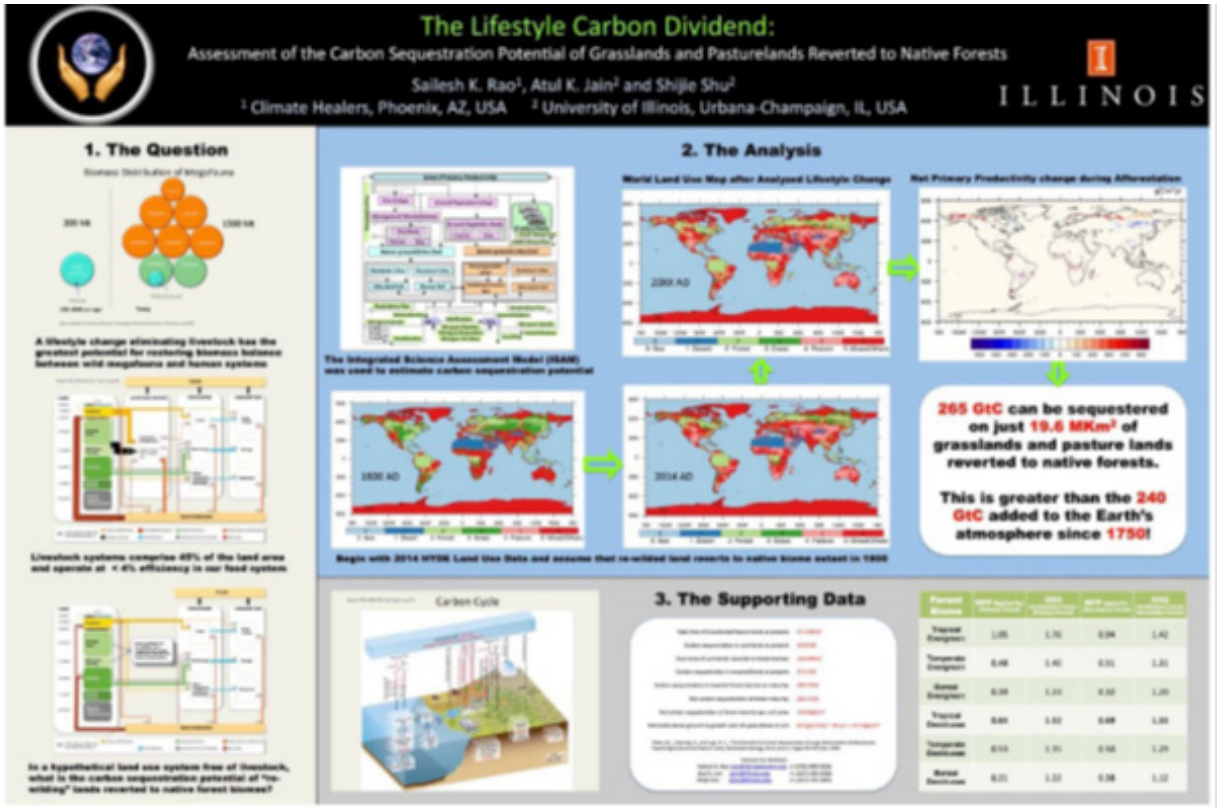

Fig 5.1. The Lifestyle Carbon Dividend analysis showing that a global transition to a plant-based economy can sequester 265 GtC on just 41% of the grazing land.

presented at the AGU Fall Meeting in 2015, we reported that 41% of this grazing land used to be forests in 1800 and that if we can return the original forests on that land, the carbon storage on land would increase by 265 GtC from its present value[15]. Our analysis was conducted using 2014 HYDE land use data, assuming that grazing land is reverted to native biomes that existed in 1800[26].

Here are the supporting calculations and extrapolations assuming that all grazing land can be regenerated to store the same carbon sequestration per unit area as the reverted lands :

Total area of grazing lands in 2014 : 47.3 M Km2

Total carbon stored in that land (soil + vegetation) : 52.8 GtC

Carbon sequestered per unit area in grazing lands : 1,116 t/Km2

Total area of grazing lands reverted to forests : 19.6 M Km2

Carbon sequestered in reverted lands at maturity : 292.7 GtC

Carbon sequestered per unit area at maturity : 14,930 t/Km2

Potential Carbon sequestration in all lands at maturity : 706.2 GtC

Net Carbon sequestration in all lands at maturity : 653.4 GtC

Net CO2 sequestration in all lands at maturity : 2396 Gt CO2

Please note that as CO2 sequestration occurs on such a massive scale, we can expect the ocean to release its dissolved CO2 and the CO2 fertilization effect to decrease on land. Then the potential CO2 sequestration will also decline proportionally, because we would be literally reducing the CO2 levels in the atmosphere, an outcome devoutly to be wished.

6. Conclusions

In this paper, we established that Animal Agriculture is the leading cause of climate change accounting for an estimated 87% of annual greenhouse gas emissions. We also illustrated the need to transition to a global plant-based economy first and that blindly eliminating fossil fuel usage first will accelerate the warming of the planet. The necessary global transition to a plantbased economy can be achieved through concerted, grassroots action, with or without the active cooperation of governments, scientific institutions, corporations and the news media.

Appendix : Four Miscalculations in IPCC Reports

In this appendix, we identify four miscalculations in the United Nations (UN) Intergovernmental Panel on Climate Change (IPCC) reports, which cause a systematic under-estimation of the impact of Animal Agriculture on climate change. For reference, we will use the data in Table SPM1, page 9, of the 2019 IPCC Special Report on Climate Change and Land[6], since it was published after the IPCC had warned humanity in 2018 of potentially catastrophic climate change by 2030, 11 short years from now[7].

The two biggest greenhouse gas contributors to climate change are carbon dioxide (CO2) and methane (CH4). Fossil fuels such as oil, coal and natural gas, produce CO2 when burned. Animal Agriculture produces methane gas through farm animals like cows. The IPCC has encouraged the public to focus on fossil fuels rather than Animal Agriculture, even though methane causes more global warming than CO2 on an annual basis. Here's how :

1. The IPCC uses total CO2 emissions instead of airborne fraction (45%)

The IPCC counts all CO2 as contributing to climate change even though less than half of all CO2 remains in the atmosphere as a warming gas on an annual basis. That miscalculation means fossil fuels are being blamed for more than their fair share of climate change, while Animal Agriculture is not getting the attention it warrants.

In Table SPM1, page 9, of its Special Report[6], the IPCC counts 39.1 Giga tons (Gt) as the average annual CO2 emissions between 2011 and 2016. National Oceanic and Atmospheric Administration (NOAA) Mauna Loa data reveals that between Jan 2011 and Jan 2016, the CO2 levels in the atmosphere increased by 2.24 ppm per year[27].

Each ppm of CO2 in the atmosphere corresponds to 7.81 Gt CO2[28].

Therefore, 2.24 ppm of CO2 corresponds to 17.6 Gt CO2, which is only 45% of the average annual emissions reported by the IPCC.

2. The IPCC measures the impact of methane over a 100 year timeframe, thereby diluting it, instead of measuring it over a decade

The IPCC badly underestimates the impact of methane gas by using a flawed timeframe of 100 years. This ignores the fact that methane decays into less harmful CO2 after only a decade. By stretching methane's impact over an entire century, the IPCC is diluting the global warming damage methane does on an annual basis, compared to C02. This is like eating a whole cake in one day, each and every Sunday, and then calculat-

ing the impact it would have on our body as if we ate it over the course of a year.

In Table SPM1, page 9, of its Special Report[6], the IPCC counts the average annual emissions of methane to be 363 Mega tons (Mt). Over a 100 year time frame, excluding climate carbon feedbacks, this works out to an equivalent CO2 emissions of 10.1 Gt CO2e, using a Global Warming Potential (GWP) of 28. This is the value shown in Table SPM1.

However, over a 10 year time frame, including climate carbon feedbacks, the GWP of methane is 130, which means that 363 Mt of methane contributes 46.9 Gt CO2e[10].

Please see Fig A.1 for the dramatic impact that the first two miscalculations have on the annual greenhouse gas emissions contribution of CO2 and methane and how it changes the framing of climate change.

3. The IPCC does not consider the opportunity cost of land use for Animal Agriculture

Most forests are destroyed to create animal grazing land. When forests vanish, so does the ability of that piece of land to cool the Earth because trees absorb carbon dioxide and the trees are gone. So, the cooling opportunity is lost. Over time, the absence of those trees means a continuous cause of climate change. Currently, 37% of the ice-free land area of the planet is used for animal grazing, but this grazing land only stores 2% of the carbon on land (see Fig A.2).

Yet, the IPCC does not consider the opportunity cost of this land use for Animal Agriculture.

4. The IPCC uses raw data from the Animal Agriculture industry

The IPCC uses raw data from the Animal Agriculture industry through the United Nations Food and Agriculture Organization (FAO), instead of neutral sources. This is like getting our data from the tobacco industry to determine cigarettes impact on health. The UN FAO has a public partnership with the International Meat Secretariat and the International Dairy Federation, two industry promotion organizations!

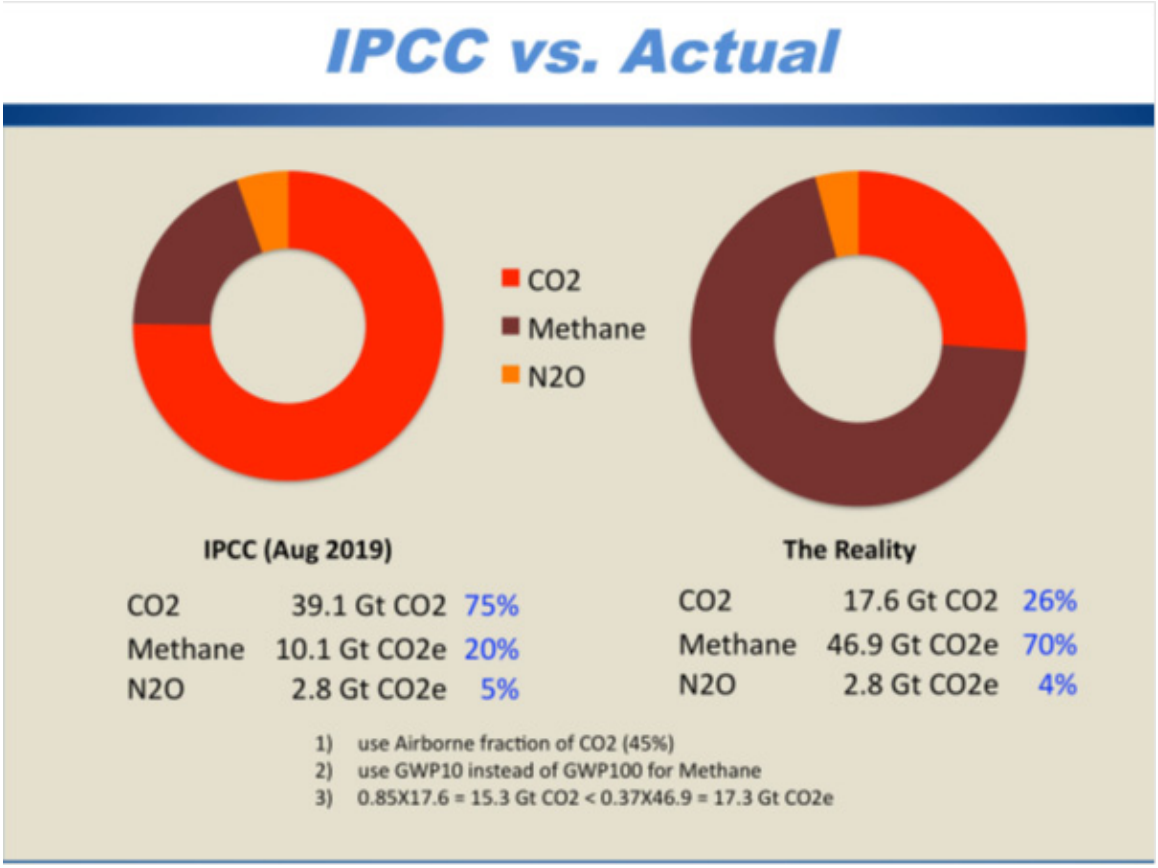

Fig. A.1. A comparison of how the IPCC calculates annual greenhouse gas emissions (see Table SPM1, page 9 of the 2019 IPCC Special Report[2]) and the reality of how the same annual greenhouse gas emissions impact climate change.

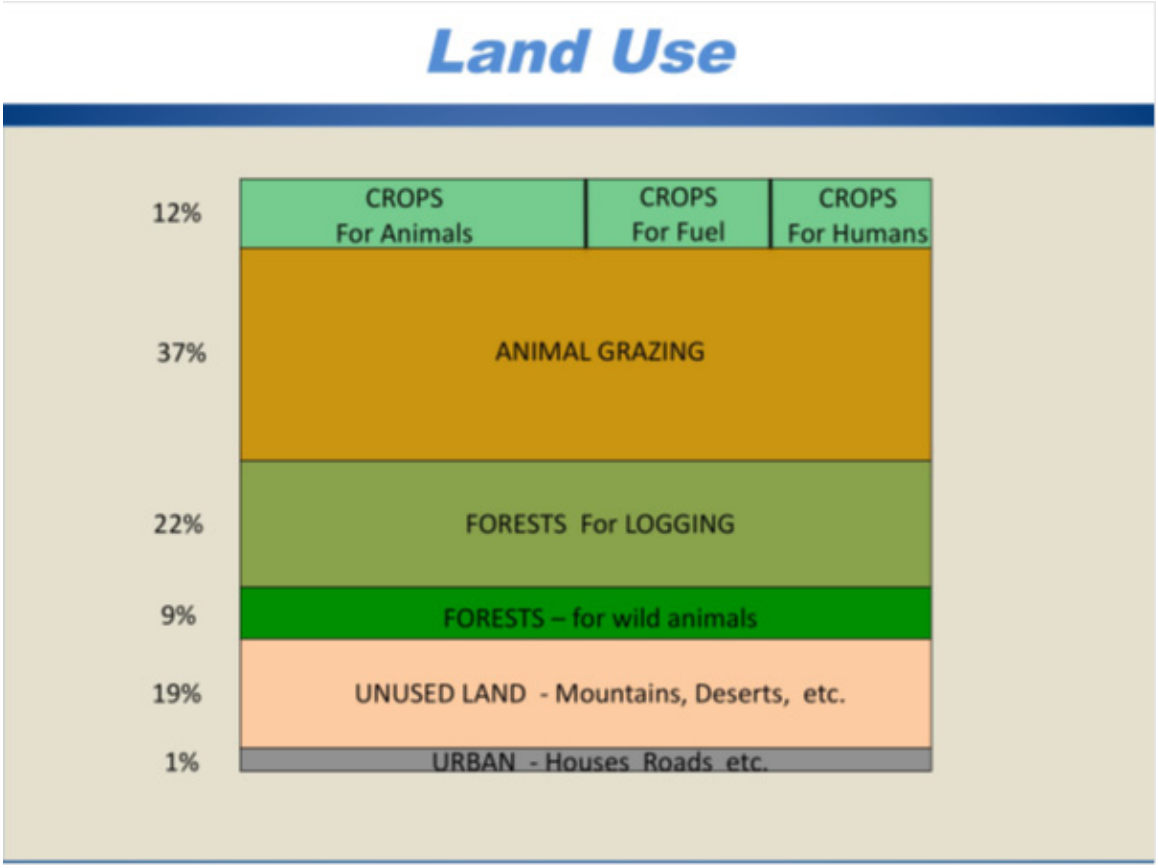

Fig. A.2. How the ice-free land area of the planet is distributed for different uses. Please note that pristine forests constitute just 9%, while Animal Grazing occurs on 37% of the land area. Source: 2019 IPCC Special Report[6].

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For source and reference links, please go to https://www.climatehealers.org/animal-agriculture-white-paper

For author's bio, please go to https://www.climatehealers.org/sailesh-rao

If you are a climate scientist and would like to publicly debate Dr. Rao on the contents of this white paper, please email us at chgroups@climatehealers.org

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3	1990	Exploitation of Nature by man
4	1991	Habitat disturbance
5	1992	Threats to ecosystems
6	1993	Projects undertaken by the Society
7	1994	Turmoil for the environment
8	1995	Conservation, bird ecology
9	1996	Vasundhara is no longer Veerabhogya!
10	1997	Barheaded Goose
11	1998	Western Ghats : Sahyadri
12	1999	Eco-restoration
13 and 14	2001-2001	Biodiversity Profile of an Urban Area
15	2002	Associations in Nature and Our Future
16	2003	Sarus Crane
17 and 18	2004-2005	Ujani Reservoir Research
19 and 20	2006-2007	Conservation of Biodiversity of the West Coast between Mumbai and Goa
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The far reaching impacts of the CoVID-19 pandemic has affected nearly every human activity, and the Journal of Ecological Society was no different. The decision to delay the 2019 journal, was a difficult one, and yet here we are with the combined issues of volumes 32 and 33.

The Journal of Ecological Society has always focussed on root cause analysis of socio-environmental issues and on ecological restoration of natural systems. The selection of articles in this issue, keeps up with this tradition.

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