Report on environmental and ecological impacts of tree felling for proposed steel flyover on Bellary Road and road widening of Jayamahal Main Road, Bengaluru

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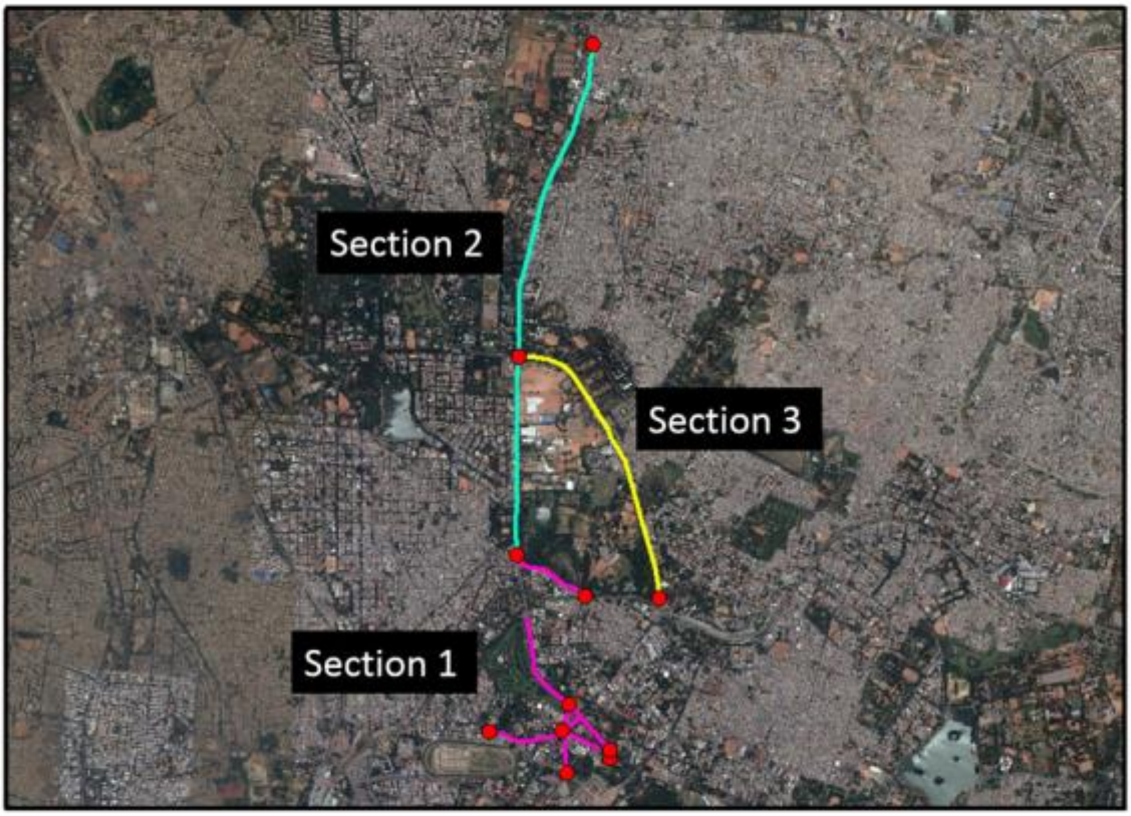
Locations of tree survey



Summary

This report presents findings from a tree census conducted to determine the number of trees that will be cut as a result of two proposed projects in Bengaluru city: the construction of a six lane elevated steel flyover extending from Basaveshwara Circle to the Hebbal flyover, and widening of the Jayamahal Main Road from Mekhri Circle to near the Cantonment Railway Station.

According to initial official estimates, the total number of trees that are to be cut for both projects number 1668. Of this 812 trees are proposed to be cut to build the steel flyover on a 6.7 km stretch (BDA 2016) and 856 trees in the 2.8 km stretch on Jayamahal Main Road (Kaggere and Chaturvedi 2016). In a later report the total number of trees from both projects that would be cut was given as 812. Of this, the authority for felling the trees numbering 567 for the steel flyover is the Bangalore Development Authority (BDA), while 245 trees for the Jayamahal Road widening will have to be cut by the Bruhat Bengaluru Mahanagara Palike (BBMP) (Chaturvedi 2017).

This report presents findings from an independent tree census, conducted by us between October 2016 and January 2017. Our census indicates that the number of trees is much higher - **2244 trees**, and **205 saplings** from **71 species** and 26 families will be cut for the projects (Annexure 1: Details of trees to be felled: Species and numbers).

These stretches were marked using the documents and videos posted by the BDA on their website and news reports for the road widening project (BDA 2016, Kaggare and Chaturvedi 2016). In some instances where it is not clear whether tree felling will impact areas – e.g. within Balabrooie – we have not taken into account those trees. Thus our estimate is **a conservative estimate of 2244 trees** and **the total number to be felled may be higher** as well.

We further describe the impact that this proposed tree felling will have in terms of **1) increasing air pollution 2) exacerbating urban heat island effects 3) impacting biodiversity 4) reducing the capacity of Bengaluru's trees for carbon sequestration 5) impacting two adjacent lakes including the buffer zone and 6) impacting the endangered Schedule 1 slender loris (*Loris tardigradus*) primate species**.

Introduction

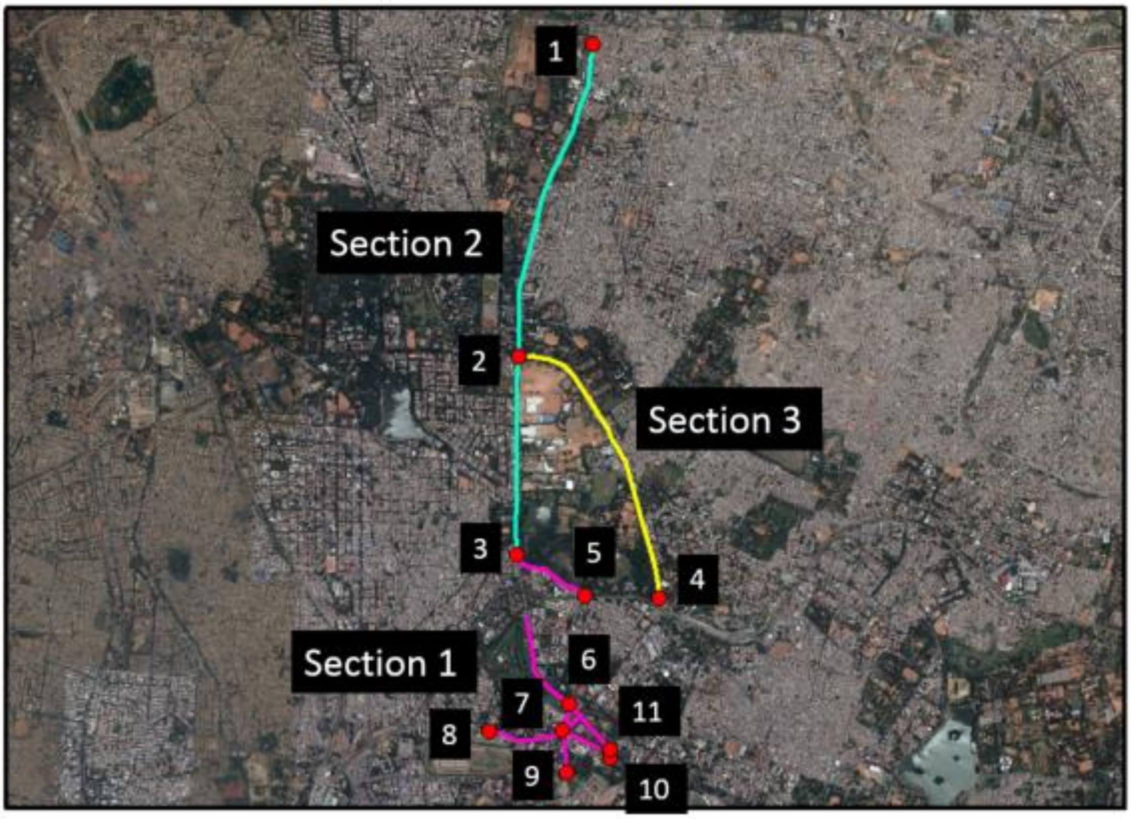
The inhabitants of the settlements in and around present day Bengaluru were well aware of the importance of trees and green spaces in their daily lives. This city, once called the Garden City of India, located in a semi-arid zone where water and tree cover was scarce, was assiduously planted, watered, greened and nurtured by successive kings, administrators and citizens. Sadly, through the centuries, we have lost the awareness of how important these resources are for the sustainability of Bengaluru. This report provides an independent scientific ecological and environmental assessment of the proposed tree felling for the construction of the steel flyover on Bellary Road, and the widening of Jayamahal Main Road. We find, even using a conservative estimate that the numbers of trees and numbers of species to be felled are far higher than Government estimates have so far claimed.

Details of trees to be felled

For the tree census the roads were divided into three sections and the tree species, girth and height were recorded for trees in each of the sections (Figure 1: Map of sections).

We found large sacred trees like the peepal (*Ficus religiosa*), keystone species with important biodiversity benefits like the fig, and economically important species like red sanders *(Pterocarpus santalinus*) and mango (*Mangifera indica*). Further, there are several massive rain trees (*Albizia saman*), African tulips (*Spathodea campanulata*) and copper pods (*Peltophorum pterocarpum*) – these have very large canopies, provide shade and reduce pollution, and harbor many of the local birds, insects and wildlife species, as also indicated by the nests that we observed on some of them. From the sizes of these trees, it is clear that many of them are several decades old, and some of them are very old and extremely large in size. Cutting these trees will have major impacts on biodiversity, air pollution and temperature in this area.

Section 1,Section 2 and Section 3



1 Hebbal flyover	4 Cantonment Station	7 Basaveshwara Circle	10 Raj Bhavan Road
2 Mekhri Circle	5 Near palace main gate	8 Race Course Circle	11 Ali Askar Road
3 Guttahalli flyover base	6 High Ground junction	9 Vidhan Soudha Circle	

Section 1 - Basaveshwara Circle to Guttahalli flyover base including ramps and underpasses

Section 2 - Guttahalli flyover base to Hebbal flyover via Mekhri Circle

Section 3 - Jayamahal Main Road from Mekhri Circle to Cantonment Station

Figure 1: Map of sections (map prepared by Enakshi Bhar, Azim Premji University)

Section I:

The first section consists of the stretch from Basaveshwara Circle till the base of the Guttahalli flyover as it descends onto Bellary Main Road. This includes the traffic islands on High Grounds and near the Windsor Manor, as well as the ramps leading to the elevated flyover and underpasses near Basaveshwara Circle. Of the four ramps, three lead onto the proposed overhead steel flyover at Basaveshwara Circle and include the: 1) ramp extending from the corner of Ali Askar Road to the High Grounds Junction 2) ramp from Vidhan Soudha Circle to Basaveshwara Circle, and 3) ramp from Race Course Circle to Basaveshwara Circle. The fourth ramp extends from Palace Cross Road to Bellary Main Road. There are two underpasses: one extends from Raj Bhavan to Race Course Road, and the other includes the road named as Basaveshwara Road (falling on a section of Millers Road). On all these stretches, trees were recorded from both sides of the roads and traffic islands. Some trees falling within the property of the Golf Course were also included in this section.

There are a total of 752 trees from 46 species in this stretch, and an additional 204 saplings. The largest number of trees are of the species *Polyalthia longifolia* (mast tree) followed by *Swietenia macrophylla* (large leaved mahogany). There are 5 species of *Ficus* numbering 33 trees in this section, that include *Ficus benjamina* (weeping fig), *Ficus amplissima* (basari), *Ficus racemosa* (cluster fig), *Ficus benghalensis* (banyan) and *Ficus religiosa* (peepal). The other wide canopied trees included the *Albizia saman* (raintree), *Delonix regia* (gulmohar), and *Peltophorum pterocarpum* (copper pod). *Michelia champaca* (champaka), *Tamarindus indica* (tamarind), *Syzigium cumini* (jamun), *Milletia pinnata* (pongam) and *Mangifera indica* (mango) are some of the other species, all of which are indigenous to the region. Flowering species such as *Tabebuia impetiginosa* (pink tabebuia), *Tabebuia rosea* (pink poi), *Lagerstroemia speciosa* (pride of India), *Cassia javanica* (Java cassia) and *Senna siamea* (yellow cassia) were also recorded in this section. There are also three trees of *Parkia biglandulosa* (badminton ball tree), and one each of *Azadirachta indica* (neem), *Artocarpus heterophyllus* (jackfruit) and *Dalbergia latifolia* (Indian rosewood).

(See Annexure 2 for details)

A majestic raintree with a girth of 620 cm is the widest and stood at a height of 20 m, while there are 15 trees whose girth was more than 300 cm. These included species of raintree, basari, cluster fig, peepal, banyan and large leaved mahogany. There are 13 very tall trees at a height of 25 m that included the species raintree, banyan, badminton ball tree, copper pod, *Simarouba glauca* (paradise tree), *Spathodea campanulata* (African tulip) and large leaved mahogany.

Trees on stretch between High Grounds Junction and Ali Askar Road junction

<u>Section II</u>:

This section extends from the base of the Guttahalli flyover as it descends onto Bellary Main Road upto the base of the Hebbal flyover. It includes the traffic island that bifurcates the road at the base of the Guttahalli flyover. Trees on both sides of the road were recorded, as well as a number of trees falling between the outer and inner wall of the palace grounds that lie along the stretch extending from Guttahalli to Mekhri Circle.

There are a total of 600 trees from 45 species in this section, plus one sapling. A peepal with a girth of 450 cm and height of 15 m is the largest tree. Additionally there are 10 trees with girth more than 300 cm, including raintree, peepal and African tulip. The tallest is a raintree at 17 m with a girth of 320 cm.

The most number of trees were of the species *Millingtonia hortensis* (Indian cork), followed by the wide canopied *Peltophorum pterocarpum* (copper pod) and the *Broussonetia papyrifera* (paper mulberry). *Tabeubia argentea* (tree of gold), *Spathodea campanulata* (African tulip) and *Senna siamea* (yellow cassia) are some of the flowering species, while *Albizia saman* (raintree), *Milletia pinnata* (pongam) and *Syzigium cumini* (jamun) are the other species recorded. *Tectona grandis* (teak), *Grevillea robusta* (silver oak), *Dalbergia sisoo* (sisoo) and *Cocos nucifera* (coconut) are among the other predominant species in this section. Two species of *Ficus, Ficus religiosa* and *Ficus racemosa* (cluster fig), as well as *Tamarindus indicus* (tamarind), *Albizia lebbeck* (siris), *Muntingia calabura*

(Singapore cherry), *Delonix regia* (gulmohar), *Bauhinia purpurea* (bauhinia), *Leucaena leucocephala* (subabul), *Polyalthia longifolia* (Indian mast) and *Artocarpus heterophyllus* (jackfruit) are the other species recorded. Additionally one tree of *Pterocarpus santalinus* (red sanders), *Azadirachta indica* (neem) and *Michelia champaca* (champaka), and two of *Bombax ceiba* (silk cotton) are present in this section.

(See Annexure 2 for details)

Guttahalli traffic island with a peepal tree

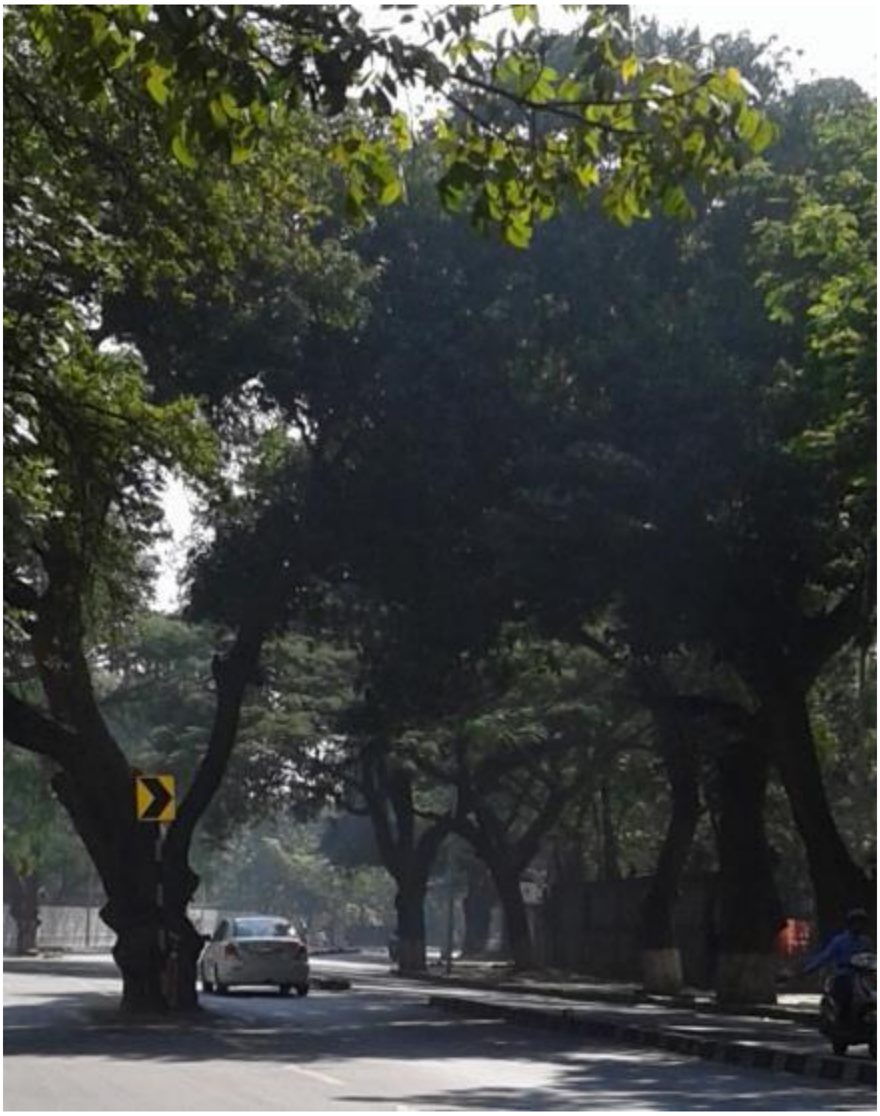
<u>Section III:</u>

This section stretches from Mekhri Circle to Cantonment Railway Station. It includes footpaths on both sides of the road, a stretch in the middle of the road between Mekhri Circle and the TV station, and trees within the palace grounds.

There are 892 trees of 45 species in this section. The most predominant is *Polyalthia longifolia* (Indian mast) followed by *Cassia javanica* (Java cassia). Very large trees of *Mangifera indica* (mango) are on the median and both sides of the road. The wide canopied *Delonix regia* (gulmohar) and *Albizia saman* (raintree), as well as *Milletia pinnata* (pongam), *Tamarindus indicus* (tamarind) and *Syzigium cumini* (jamun) are other common species. There are a number of *Caryota urens* (fish tail palm). *Terminalia catappa* (desi badam), *Couroupita guianensis* (cannon ball tree), *Bauhinia purpurea* (buhinia), *Artocarpus heterophyllus* (jackfruit), *Guazuma ulmifolia* (honeyfruit) and *Albizia lebbeck* (siris) are some additional species. There are single trees of *Azadirachta indica* (neem), *Butea monosperma* (flame of the forest), *Madhuca longifolia var latifolia* (mahua) and *Parkia biglandulosa* (badminton ball tree). *Ficus* species recorded were *Ficus elastica* (rubber tree), *Ficus mysorensis* (Mysore fig), *Ficus benghalensis* (banyan) and *Ficus religiosa* (peepal). *Jacaranda mimosifolia* (jacaranda), *Syzigium jambos* (rose apple), *Gmelina arborea* (shivane), *Ziziphus mauritiana* (Indian jujube), *Michelia champaca* (champaka) and *Tectona grandis* (teak) were also present.

(See Annexure 2 for details)

With a girth of 623 cm, a raintree is the widest, while the tallest tree at 25 m is a *Spathodea campanulata* (African tulip). Additionally, there are 31 trees with a girth exceeding 300 cm that included mango, African tulip, jamun, Mysore fig, siris, *Grevillea robusta* (silver oak), gulmohar. Several trees of mango are present in the road median, the widest having a girth of 455 cm and a height of 20 m.



The towering mango trees on Jayamahal Main Road

Lake ecosystems that will be impacted

In addition to the loss of the trees, there are two lakes that will also be impacted as a result of the steel flyover. Hebbal lake, an ancient water body believed to have been built by Kempe Gowda I, the founder of Bengaluru city, extending across 57.75 ha is one of the lakes. A second lake is located within the palace grounds at a distance of 59 m from the existing road over which the steel flyover is proposed. Given the recent ruling of the National Green Tribunal on May 4, 2016 stating that the buffer zone should be at least 75 metres from the boundary of a lake, **the proposed steel flyover will be in violation of the buffer zone for the palace lake.**

The Hebbal lake has several islands that serve as habitats for a variety of bird species, and is a haven for migratory birds. The lake situated within the palace grounds is a large water body that also supports a variety of bird life.

Additionally, other fauna such as snakes and frogs can be found, and in the case of the lake in the palace grounds, its periphery and surroundings are ringed by a variety of trees. **The endangered slender loris, protected as a Schedule 1 species under the Indian Wildlife (Protection) Act 1972, is found in the areas adjacent to the palace lake and will be impacted by the construction of the steel flyover.**

Lake within the palace grounds, located close to the road

Environmental impacts from loss of trees and surrounding ecosystems

1. Increased Air Pollution

Air pollution has become a leading cause of debilitation and death in many Indian cities. Green spaces are very important to act as lungs for the city, producing oxygen and removing carbon dioxide. Trees in Bengaluru help to reduce levels of harmful air pollutants such as sulphur dioxide and Suspended Particulate Matter substantially, bringing these within permissible limits.

Our previous research has found that street trees have a significant impact on air pollution in Bangalore, reducing Suspended Particulate Matter levels by as much as 75% on roads (thus reducing the likelihood of asthma and other pollution related health disorders). Sulphur dioxide levels in road segments with tree cover are kept within permissible limits (Vailshery et al 2013)

Trees mitigate the impact of dust pollution: a product of the incessant construction along these stretches. All stretches of the roads see continuous vehicular traffic, and the presence of the trees help keep the pollution from vehicular exhaust in check. Suspended Particulate Matter and air quality of Bengaluru has been a cause for concern in recent years (Rukmini 2015), and loss of tree cover as a result of the two proposed projects will severely compound the problem. Bengaluru will soon have to suffer a fate similar to that of the capital New Delhi, where the city was described as a 'gas chamber' owing to high levels of air pollution compounded by firecrackers during the annual Diwali festival (BBC 2016).

2. Urban heat islands

Trees help to reduce the temperature on road surfaces and surrounding areas considerably. As shown in our previous research in Bengaluru, trees on roads reduced ambient air temperatures by as much as 5.6°C, and reduced road asphalt surface temperatures by as much as 27.5°C in Bengaluru (Vailshery et al 2013). Cutting trees on these roads for the proposed projects will mean an irreversible loss of this free temperature regulation provided by nature even as temperatures in Bengaluru are soaring every year. In April 2016, Bengaluru recorded its hottest summer in 85 years with the temperature rising to 39.2°C (The Indian Express 2016).

3. Loss of biodiversity

Trees even along congested roads, especially the fruiting varieties, provide food and nesting habitat for birds. The one-time loss of 2244 trees will reduce the available habitat for several species of birds, not to mention insects and other mammals such as bats. The keystone species especially *Ficus sp* serve as habitats for a wide variety of biodiversity. Many trees such as the *Ficus religiosa* (peepal) and *Ficus racemosa* (cluster fig) are also sacred trees revered by many residents of the city.

4. Carbon sequestration

Trees act as sinks or reservoirs that sequester carbon for long periods thereby playing a critical role in addressing global warming and impacts of climate change. Trees store carbon that is referred to as biomass, and while roots, debris and litter all contribute to the biomass, the portion of the trees above the ground comprises the predominant portion of the carbon stock. While young trees are known to absorb carbon in their growing stage, recent research has also shown that older trees fix large amounts of carbon (Stephenson et al 2014). Many of the trees that are to be affected by the projects are old, and cutting them would drastically reduce carbon absorbed and contribute to climate change.

In order to estimate how much of carbon was sequestered by the 2244 trees, the above ground biomass (AGB) was calculated for 2176 trees. We excluded 68 trees of species for which we could not locate the species-specific wood density measures required to calculate the AGB from tree measurements. The total AGB for the 2176 trees amounted to 159,238.90 kg/cm^3, while the BGB is estimated between 38,217.34 kg/cm^3 to 58,918.39 kg/cm^3 .Together this amounts to an average of 98.5 metric tonnes of carbon.

Estimates of carbon storage in US cities give a range from 19,300 metric tonnes of carbon in Jersey City, to 2.2 million metric tonnes of carbon in New York, NY (Nowak and Crane, 2002). Thus, assuming that trees in Bengaluru sequester an equivalent amount of carbon as trees in US cities, **trees play a significant role in carbon sequestration in Bengaluru**. Given the urgency of global climate change, this is an important aspect of the role of street trees that needs to be stressed.

(See Annexure 3: Calculation of AGB, BGB and carbon content)

5. Impact on lakes

The construction of the steel flyover will disturb the nesting sites of birds in both lakes. In the case of Hebbal, the ecosystem has already been affected owing to its conversion in part to a park and the flyover built adjacent to it. One of the visible signs has been the reduction in bird numbers and species visiting the lake in the recent years as noted by naturalists and bird watchers (Kannan 2013, Rao 2015). The construction of the steel flyover will mean a further loss to the biodiversity of the lake.

The lake within the palace grounds is relatively undisturbed as yet, but construction so close to it will harm the biodiversity that take refuge in it. Additionally, the steel flyover would be in violation of a ruling passed by the National Green Tribunal in 2016 (NGT 2016, Routray 2016). According to this order a buffer zone of 75 m needs to be provided around lakes. The proposed construction of the steel flyover at a distance of 59 m from the edge of the lake in the palace property would thus be in violation of this ruling.

Lakes and the surrounding greenery in the city provide several ecological benefits. Lakes help recharge the groundwater. Trees are critical to increase water retention, absorb water and slow down the rate of run-off, providing effective ground water recharge. Trees also help to stabilise soil and channel water safely, reducing the intensity of rainfall on roads in the monsoon and reducing incidences of flash flooding. Flooding is another calamity that Bengaluru has been witness to as well in recent years causing much loss to property (The Scroll 2016). Flooding also brings with it the threat of infections from stagnant water and vector borne diseases such as dengue and malaria.

The green cover of Bengaluru is fast diminishing, especially in its public spaces. What little greenery the city has that contributes positively to maintaining the micro-climate, mitigating the dust and noise pollution is often situated in pockets such as those in the palace grounds and other institutional spaces (Nagendra et al 2012). These last green lungs of Bengaluru need to be protected.

6. Impacting the endangered slender loris

Recently a slender loris (*Loris tardigradus*), a nocturnal primate, was rescued from a road adjacent to the one where the steel flyover is proposed (The Deccan Herald, Sep 20, 2016). The presence of these primates is reported in several parts of the city, and yet very little is actually known about their population. The slender loris is categorised as "Endangered" by the IUCN Red List (IUCN 2008), and is a listed under Schedule I of the Indian Wildlife (Protection) Act 1972. They are an indicator[1] species in an urban environment and their presence in Bengaluru city supports the existence of a wide variety of other urban flora and fauna (Soumya 2015). The tree cover along roads and adjacent to the green areas such as the palace grounds are ideal sites for the slender loris. Reports indicate that the loris has been seen in areas of the palace adjacent to the proposed sites of tree felling. The slender loris requires areas of dense vegetation with continuous tree cover (Kar Gupta 2007). The survival of these endangered species will be threatened significantly if the wooded patches where it is located are fragmented due to tree felling, and disturbed by road widening and construction of the steel flyover, with the associated noise, lights, dust, pollution and movement of traffic.

Conclusion and Recommendations

Various government reports list between 812 and 1668 trees to be felled, belonging to 45 species of trees, as a result of two projects – construction of the steel flyover on Bellary Road, and the widening of Jayamahal Main Road. In our study, we find much higher numbers of trees and species. A conservative estimation (which does not take into account trees from areas where felling may

[1] A species whose presence or absence is indicative of the overall health of an ecosystem

be likely but not certain) reveals that **at least 2244 trees from 71 species** will be affected by tree felling.

Government reports also identify 11 areas for replanting of 60,000 trees. Previous experience with compensatory plantation of trees in Bengaluru does not give us much confidence that this replantation will be conducted, or that it will result in the survival and growth of a majority of the saplings planted. If this were to be the case, the tens of thousands of trees that have been cut in Bengaluru over the past decade or so should have been replaced with millions of trees, resulting in a substantially greener city by now!

We should by now disabuse ourselves of the notion that the environmental and ecological benefits provided by a large mature tree can be easily replaced in a short time frame by planning a number of small saplings. It takes years for a sapling to reach the size of a large mature tree, and provide similar ecological and environmental benefits. Also, the survival rates of saplings planted in the urban context is often quite poor, and many of these saplings may not survive to maturity in the first place.

The proposed replanting of saplings is in localities away from the site of this project. This fails to address the problem of air and noise pollution, heat islands, and biodiversity impact within this area. The existing trees on this stretch are large wooded trees that have been standing here for decades mitigating the impacts of pollution and high temperatures: planting saplings in far off sites cannot replace this service provided.

With the disappearance of hundreds of thousands of trees in the last two decades from the central areas of the city, the few remaining large wooded stretches of trees – of which the trees on Bellary Road and Jayamahal Main Road are a stellar example - are very important for Bengaluru. Trees provide the following services

- Air pollution has become a leading cause of debilitation and death in many Indian cities. Green spaces are very important to act as lungs for the city, producing oxygen and removing carbon dioxide. Trees in Bengaluru help to reduce levels of harmful air pollutants such as sulphur dioxide and Suspended Particulate Matter substantially, bringing these within permissible limits.

- During the summer, the city experiences severe urban heat island effects. Street trees can help to reduce the heating of concrete and asphalted surfaces by over 20°C, and reduce air temperature by at least 3-5°C in Bengaluru.

- Trees are also very important habitats for urban biodiversity. Many varieties of birds, butterflies, reptiles, bats, primates and many other fauna are found in abundance around wooded stretches.

- Bengaluru is facing a severe ground water crisis. Trees are critical to increase water retention, absorb water and slow down the rate of run-off, providing effective ground water recharge. Trees also help to stabilise soil and channel water safely, reducing the intensity of rainfall on roads in the monsoon and reducing incidences of flash flooding.

North Bengaluru constitutes one of Bengaluru's few remaining green spots thanks in large part to the wooded roads of Bellary and Jayamahal, and the greenery provided by campuses such as the palace and Sankey lake. The ecological and environmental integrity of north Bengaluru is threatened by the spectre of massive tree felling which will create noise, pollution, heat and fragment the urban habitat. The green stretch of trees alongside Bellary Road and Jayamahal Main Road, with wooded patches abutting it from the palace, provides a rare and important haven for nature, and an important lung space for the city. It needs to be protected from the challenges of urbanization: both for the survival of the thriving biodiversity around the area, and for the lakhs of local residents who benefit from the green surroundings through clean air, comfortable ambient temperatures, and the mental and physical benefits that come from access to nature and greenery in a frenetic city.

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Annexures

Annexure 1: Details of trees to be felled: Species and numbers					
Scientific name	*Common name*	*Family*	*No of trees*	*No of saplings*	*Total*
Acacia ferruginea	Banni	Fabaceae	3	0	3
Acacia leucophloea	White barked acacia	Fabaceae	1	0	1
Albizia lebbeck	Siris	Fabaceae	14	0	14
Albizia saman	Raintree	Fabaceae	63	4	67
Alstonia macrophylla	Batino	Apocynaceae	1	0	1
Alstonia scholaris	Devil's tree	Apocynaceae	6	0	6
Aphanamixis polystachya	Pithraj	Meliaceae	1	0	1
Artocarpus heterophyllus	Jackfruit	Moraceae	13	0	13
Azadirachta indica	Neem	Meliaceae	3	0	3
Bauhinia purpurea	Bauhinia	Fabaceae	19	0	19
Bixa orellana	Achiote	Bixaceae	2	0	2
Bombax ceiba	Silk cotton	Malvaceae	2	1	3
Broussonetia papyrifera	Paper mulberry	Moraceae	109	4	113
Butea monosperma	Flame of the forest	Fabaceae	1	0	1
Caryota urens	Fish tail palm	Arecaceae	14	0	14
Cassia javanica	Java cassia	Fabaceae	185	0	185
Cocos nucifera	Coconut	Arecaceae	14	0	14
Cordia wallichii	Indian cherry	Boraginaceae	2	0	2
Couroupita guianensis	Cannon ball tree	Lecythidaceae	9	0	9
Dalbergia latifolia	Indian rosewood	Fabaceae	1	0	1
Dalbergia sissoo	Sissoo	Fabaceae	16	0	16
Delonix regia	Gulmohar	Fabaceae	55	0	55
Eucalyptus globulus	Eucalyptus	Myrtaceae	2	0	2
Ficus amplissima	Basari	Moraceae	5	0	5
Ficus benghalensis	Banyan	Moraceae	11	4	15
Ficus benjamina	Weeping fig	Moraceae	2	0	2
Ficus elastica	Rubber tree	Moraceae	1	0	1
Ficus mysorensis	Mysore fig	Moraceae	1	0	1
Ficus racemosa	Cluster fig	Moraceae	12	1	13
Ficus religiosa	Peepal	Moraceae	16	5	21
Filicium decipiens	Fern leaf tree	Sapindaceae	5	0	5
Gmelina arborea	Shivne	Lamiaceae	2	0	2
Grevillea robusta	Silver oak	Proteaceae	66	0	66
Guazuma ulmifolia	Honeyfruit tree	Malvaceae	10	0	10
Jacaranda mimosifolia	Jacaranda	Bignoniaceae	5	0	5
Kigelia africana	Sausage tree	Bignoniaceae	7	0	7
Lagerstroemia speciosa	Pride of India	Lythraceae	25	0	25
Leucaena leucocephala	Subabul	Fabaceae	21	3	24
Madhuca longifolia var latifolia	Mahua	Sapotaceae	1	0	1
Mangifera indica	Mango	Anacardiaceae	61	0	61
Manihot glaziovii	Ceara rubber tree	Euphorbiaceae	3	0	3
Manilkara zapota	Sapota	Sapotaceae	2	0	2
Markhamia lutea	Nile tulip tree	Bignoniaceae	31	0	31

Melaleuca bracteata	Black tea tree	Myrtaceae	8	7	15
Melia azedarach	Persian lilac	Meliaceae	4	0	4
Michelia champaca	Champaka	Magnoliaceae	9	0	9
Millettia pinnata	Pongam	Fabaceae	85	1	86
Millingtonia hortensis	Indian cork tree	Bignoniaceae	96	0	96
Muntingia calabura	Singapore cherry	Muntingiaceae	12	0	12
Parkia biglandulosa	Badminton ball tree	Mimosaceae	8	0	8
Peltophorum pterocarpum	Copper pod	Fabaceae	147	0	147
Phoenix sylvestris	Wild date palm	Arecaceae	26	0	26
Pithecellobium dulce	Manila tamarind	Fabaceae	1	0	1
Polyalthia longifolia	Mast tree	Annonaceae	500	126	626
Pterocarpus marsupium	Indian kino tree	Fabaceae	2	0	2
Pterocarpus santalinus	Red sandalwood	Fabaceae	1	0	1
Roystonea regia	Royal palm	Arecaceae	7	0	7
Senna siamea	Yellow cassia	Fabaceae	26	0	26
Simarouba glauca	Paradise tree	Simaroubaceae	8	0	8
Spathodea campanulata	African tulip	Bignoniaceae	43	0	43
Swietenia macrophylla	Large leaved mahogany	Meliaceae	220	28	248
Syzygium cumini	Jamun	Myrtaceae	39	0	39
Syzygium jambos	Rose apple	Myrtaceae	2	0	2
Tabebuia argentea	Tree of gold	Bignoniaceae	22	0	22
Tabebuia impetiginosa	Pink tabebuia	Bignoniaceae	43	21	64
Tabebuia rosea	Pink poui	Bignoniaceae	28	0	28
Tamarindus indica	Tamarind	Fabaceae	24	0	24
Tectona grandis	Teak	Verbenaceae	28	0	28
Terminalia catappa	Desi badam	Combretaceae	10	0	10
Thespesia populnea	Behndi tree	Malvaceae	5	0	5
Ziziphus mauritiana	Indian jujube	Rhamnaceae	2	0	2
Unknown species			15	0	15
TOTAL			2244	205	2449

Annexure 2: Tree numbers and species in Sections I, II and III						
Species	*Common name*	*Family*	*SECTIONS**			*Sapling*
			I	*II*	*III*	
Acacia ferruginea	Banni	Fabaceae		1	2	
Acacia leucophloea	White barked acacia	Fabaceae		1		
Albizia lebbeck	Siris	Fabaceae		8	6	
Albizia saman	Raintree	Fabaceae	18	28	17	4
Alstonia macrophylla	Batino	Apocynaceae	1			
Alstonia scholaris	Devil's tree	Apocynaceae	4	2		
Aphanamixis polystachya	Pithraj	Meliaceae			1	
Artocarpus heterophyllus	Jackfruit	Moraceae	1	3	9	
Azadirachta indica	Neem	Meliaceae	1	1	1	
Bauhinia purpurea	Bauhinia	Fabaceae	5	5	9	
Bixa orellana	Achiote	Bixaceae		2		
Bombax ceiba	Silk cotton	Malvaceae		2		1
Broussonetia papyrifera	Paper mulberry	Moraceae	9	51	49	4
Butea monosperma	Flame of the forest	Fabaceae			1	
Caryota urens	Fish tail palm	Arecaceae			14	
Cassia javanica	Java cassia	Fabaceae	12	1	172	
Cocos nucifera	Coconut	Arecaceae	2	12		
Cordia wallichii	Indian cherry	Boraginaceae		2		
Couroupita guianensis	Cannon ball tree	Lecythidaceae			9	
Dalbergia latifolia	Indian rosewood	Fabaceae	1			
Dalbergia sissoo	Sissoo	Fabaceae		16		
Delonix regia	Gulmohar	Fabaceae	12	6	37	
Eucalyptus globulus	Eucalyptus	Myrtaceae	2			
Ficus amplissima	Basari	Moraceae	5			
Ficus benghalensis	Banyan	Moraceae	9		2	4
Ficus benjamina	Weeping fig	Moraceae	2			
Ficus elastica	Rubber tree	Moraceae			1	
Ficus mysorensis	Mysore fig	Moraceae			1	
Ficus racemosa	Cluster fig	Moraceae	8	4		1

Ficus religiosa	Peepal	Moraceae	9	5	2	5
Filicium decipiens	Fern leaf tree	Sapindaceae	1	3	1	
Gmelina arborea	Shivne	Lamiaceae			2	
Grevillea robusta	Silver oak	Proteaceae	1	23	42	
Guazuma ulmifolia	Honeyfruit tree	Malvaceae	1	1	8	
Jacaranda mimosifolia	Jacaranda	Bignoniaceae	1	2	2	
Kigelia africana	Sausage tree	Bignoniaceae	4	3		
Lagerstroemia speciosa	Pride of India	Lythraceae	25			
Leucaena leucocephala	Subabul	Fabaceae	8	10	3	3
Madhuca longifolia var longifolia (also var latifolia)	Mahua	Sapotaceae			1	
Mangifera indica	Mango	Anacardiaceae	10		51	
Manihot glaziovii	Ceara rubber tree	Euphorbiaceae		3		
Manilkara zapota	Sapota	Sapotaceae			2	
Markhamia lutea	Nile tulip tree	Bignoniaceae	24	1	6	
Melaleuca bracteata	Black tea tree	Myrtaceae	8			7
Melia azedarach	Persian lilac	Meliaceae	4			
Michelia champaca	Champaka	Magnoliaceae	5	1	3	
Millettia pinnata	Pongam	Fabaceae	6	31	48	1
Millingtonia hortensis	Indian cork tree	Bignoniaceae		94	2	
Muntingia calabura	Singapore cherry	Muntingiaceae	1	5	6	
Parkia biglandulosa	Badminton ball tree	Mimosaceae	3	4	1	
Peltophorum pterocarpum	Copper pod	Fabaceae	12	82	53	
Phoenix sylvestris	Wild date palm	Arecaceae	14	12		
Pithecellobium dulce	Manila tamarind	Fabaceae			1	
Polyalthia longifolia	Mast tree	Annonaceae	304	11	185	126
Pterocarpus marsupium	Indian kino tree	Fabaceae			2	
Pterocarpus santalinus	Red sandalwood	Fabaceae		1		
Roystonea regia	Royal palm	Arecaceae		7		
Senna siamea	Yellow cassia	Fabaceae	11	11	4	
Simarouba glauca	Paradise tree	Simaroubaceae	4	4		
Spathodea campanulata	African tulip	Bignoniaceae	9	20	14	

Swietenia macrophylla	Large leaved mahogany	Meliaceae	106	36	78	28
Syzygium cumini	Jamun	Myrtaceae	6	22	11	
Syzygium jambos	Rose apple	Myrtaceae			2	
Tabebuia argentea	Tree of gold	Bignoniaceae	1	21		
Tabebuia impetiginosa	Pink tabebuia	Bignoniaceae	43			21
Tabebuia rosea	Pink poui	Bignoniaceae	28			
Tamarindus indica	Tamarind	Fabaceae	7	6	11	
Tectona grandis	Teak	Verbenaceae		23	5	
Terminalia catappa	Desi badam	Combretaceae	1		9	
Thespesia populnea	Behndi tree	Malvaceae	1	4		
Ziziphus mauritiana	Indian jujube	Rhamnaceae			2	
Unknown species			2	9	4	
TOTAL			752	600	892	205

*Section I: Basaveshwara Circle including ramps leading to steel flyover at the circle to Guttahalli flyover base
Section II: Guttahalli flyover base to Hebbal flyover base
Section III: Mekhri Circle to Cantonment Railway Station

Annexure 3: Calculation of AGB, BGB and carbon content, along with references

Calculation of AGB

The AGB gm/cm^3 was calculated by using the equation: π*r^2*h*wood density* taper value

π =3.14159; Radius (r) = tree girth/2π, measured in field; Height (h) = measured in field

taper value= 0.06 (Source: Chave J, C Andalo, S Brown, MA Cairns et al. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia, 145: 87-99.)

Wood density:

Wherever available, wood density values within India were considered first. In the absence of the same the values available for the region closest were taken and if not any available wood density value was used. Where there were multiple values, an average was taken. Wood density of species was accessed from the below sources:

Zanne, A.E., Lopez-Gonzalez, G.*, Coomes, D.A., Ilic, J., Jansen, S., Lewis, S.L., Miller, R.B., Swenson, N.G., Wiemann, M.C., and Chave, J. 2009. Global wood density database. Dryad. Identifier: http://hdl.handle.net/10255/dryad.235.

Purkayastha, SK. Edition 1: 1996, Ed 2: 1997. A manual of Indian timbers (with description of their gross anatomical structure, properties and uses). Sribhumi Publishing Company Calcytta 700 009. For Forest Research Institute, Dehra Dun

Reyes, G., S Brown, J Chapman, AE Lugo. 1992. Wood densities of tropical tree species. General Technical Report. United States Department of Agriculture , New Orleans, Louisiana

Orwa C, A Mutua, Kindt R , Jamnadass R, S Anthony. 2009 Agroforestree Database:a tree reference and selection guide version 4.0 (http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp)

Calculation of below ground biomass (BGB)

The Below Ground Biomass is estimated between 24 to 37% of AGB (Source: Martin AR, SC Thomas. 2011. A reassessment of carbon content in tropical trees. Plos One, 6(8): e23533. doi:10.1371/journal.pone.0023533).

Calculation of carbon content

The AGB and BGB figures were converted to C using a conversion factor of 47.4% (Source: Martin AR, SC Thomas. 2011. A reassessment of carbon content in tropical trees. Plos One, 6(8): e23533. doi:10.1371/journal.pone.0023533).