

Status of Tree Cover in Urban Areas of Gujarat



(Trees in Municipal Corporations and Municipalities)
Tree counting in urban and sub-urban areas - 2011



Gujarat Forest Department

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Message

Gujarat has recorded highest decadal economic growth in the country and has simultaneously taken several initiatives, including establishing a separate department for climate change to protect environment. The State is a leader in promotion of sustainable energy options and has been a front runner in development of solar energy. Also, Gujarat is all set to become the first state in the country to generate solar power through panels mounted on canals, which will be supplied to villages alongside the canal, leading to multiple use of land, lower transmission losses and also reduced evaporation from canal. The Government is also working to raise tree plantations along the Narmada canals and the command areas to expand green cover in the state. Trees are important part of human life and play significant environment amelioration role in the urban areas. They are on the job twenty four hours every day working for all of us to improve our environment and quality of life. They play a role in improving air and water quality and provide variety of environmental and social benefits. In other words, trees are major environment capital assets in cities that require care and maintenance. In Gujarat, several cities like Gandhinagar, Vadodara and Bhavnagar have adequate tree cover, ameliorating the urban environment and providing recreational value to the people, but several others need to increase tree cover in favour of improving health of urban environment.

Initiative by the Forest Department to survey trees and assess the tree cover in the area of municipal corporations and municipalities is appreciable. I congratulate the Forest Department in bringing out such an important report on **“Status of Tree Cover in the Urban Areas in Gujarat State”**, which will help the government to design appropriate plans to improve green cover in the urban areas.

Narendra Modi

Chief Manager, Gujarat State



Message

Gujarat is considered growth engine of India and has been equally concerned of environment. The efforts at improving environment include enhancement of tree cover. Sustained efforts in the field of social forestry have yielded positive results with tree cover showing positive trend over a period. The impact is found pronounced in many parts of state largely in rural areas. The high pace of urbanization in the recent years caused concern among urbanites and planners for urban tree cover. Tree cover in urban areas is critical for improving the human environment and also the health of people. Recognising the roles of trees in cities and towns, Gujarat has taken several initiatives like creation of cultural forests, implementation of **nagar nandan yojana** and tree plantation in campaign mode. However, these efforts may not be adequate. Raising tree plantation blocks and scattered trees around ponds/lakes, buildings and streets should be treated as an environmental infrastructure in the urban areas.

To assess the impact and ground situation, the Social Forestry Wing of the Forest Department has taken another initiative to assess tree cover in the **Mahanagar Palikas** and **Nagar Palikas**. I congratulate the officers of the Forest Department for publishing report on **Status of Tree Cover in the Urban Areas in Gujarat State**, which will be of immense use for planning urban forestry in the state.

Mangubhai Patel

Minister,
Tribal Welfare, Forests & Environment,
Gujarat State



Message

Green space and adequate area under tree cover is essential to maintain environment of the cities and towns. Urban areas do not have only local environmental impacts but also large ecological footprints. Although tree plantation has been done on a large scale in the urban areas, it may not be adequate to meet the growing need of trees in the expanding urban areas. There is a need to raise large scale successful tree plantations by planting tall seedlings to address growing environmental problems in the cities. To assess tree cover and also to design appropriate urban forestry programme, the Social Forestry Wing of the Gujarat Forest Department estimated tree cover in all municipal corporations and municipalities, and is bringing out a report on Status of Tree Cover in the Urban Areas in Gujarat State. The result provides valuable observations. The data from this survey shall help in developing strategy and action plan to meet the requirement of tree cover in urban areas of Gujarat. I congratulate the officers of the Social Forestry Wing of the Forest Department who have taken pain to carry out such exercise in all cities and towns and have prepared an outstanding report.

Kiritsinh Rana

Minister of State,
Forests & Environment, Gujarat State



Message

The most explosive urban growth is expected in some of the Asian region, particularly, in Gujarat where about half of the State population may live in the cities and towns in the next decade. As bulk of human population shifts from rural to urban areas, paucity of the green space is becoming an increasingly urban phenomenon. Urban areas in the developing countries have multi-faceted problems like paucity of safe water, inadequate waste management, pollution, occupation and degradation of sensitive lands, flooding, poor oxygen level, poor tree cover and inadequate green cover. The urbanization has variety of impacts: conversion of agricultural or tree cover lands for urban uses and infrastructure, pollution or reclaiming of wetlands, increasing impervious cover on earth surface, and excavation of sand and loss of trees. To improve health of urban environment, campaign for improving tree cover is unavoidable in the cities and towns.

Gujarat has already taken lead in the environmental front and greening urban areas is one of such initiative. Tree plantation in campaign mode has been taken up in several cities like Ahmedabad, Surat and Vadodara but its success has been debated. Thus, it is necessary to take up certain necessary measures like proper planning, plantation of tall seedlings of suitable species, adequate caring and protection measures to achieve higher success rate. Also, there was a need to generate adequate information about the status of trees in the urban areas of Gujarat. Initiative of the Forest Department to assess tree cover in cities and towns and publication of a report on Status of Tree Cover in the Urban Areas in Gujarat State is appreciable, as this document may lay a sound foundation for developing action plan to green growing urban areas in Gujarat State.

Dr. S. K. Nanda, IAS

Principal Secretary,
Forests and Environment Department,
Gujarat State



Foreward

Tree cover in urban areas around the world, is declining and impervious cover is increasing due to the demand of the land for development. Amongst all the capitals of the states of India, Gandhinagar, Bangalore, Chandigarh, New Delhi, and Dehradun are few green cities which have relatively good tree cover and natural environment. The planned development of some of these cities present a picture of cities that are clean and green with trees, plants, lakes and parks. Indian cities, particularly cities and towns in Gujarat are growing at fast pace in terms of urbanization, technology, infrastructure, and environment. The pace of urbanization is adversely affecting the green cover in the urban areas. There is a need of awareness campaign that sensitise urban society on issues of environment, hygiene, sanitation including solid waste management, tree protection and help in greening urban landscapes.

Trees provide numerous environmental, social and economic benefits to people and their services in maintaining environment has been universally accepted. Thus, when more than half of the human population is expected to live in the urban areas in Gujarat, it is necessary to improve tree cover in the cities and towns. Environmental problems are progressively taking alarming dimensions. The tree canopies moderate temperature, provide shade to building, area of sidewalk, streets and reduce pollution. Tree cover in the urban areas should be treated as important and essential constituent of urban infrastructure. Although different cities of the Gujarat State has had campaigns implemented activities to raise trees in urban area but efforts are not adequate. Estimation of tree population and tree cover in urban area and publication of a report on the status of tree cover in municipal corporations and municipalities shall be of immense use for developing appropriate action plan to improve tree cover for all urban areas of the state.

Pradeep Khanna

Head of the Forest Force &
Principal Chief Conservator of Forests,
Gujarat State

About Tree Survey and Counting

Over half of the human population in Gujarat will live in the urban areas in the next decade. The urban forests, woodlands, tree groves, parks and garden and setting of trees along streets and around buildings not only moderate urban environment but also contribute significantly to improve quality of human life. As a result, urban forestry advocates the role of trees as a critical part of the urban infrastructure. Trees are usually selected, planted, trimmed, and nurtured by people, often with specific intentions, in the urban areas. Thus, it has become necessary to know the status of tree cover and also scope of improving it in the interest of people. In the background of this fact and also to provide basic information for planning of future urban forestry in the state, it was decided to estimate tree cover and also the status of trees in the urban areas.

Social Forestry Wing of the Gujarat Forest Department has taken several landmark initiatives, and survey of trees in the rural areas in 2003 and then again 2009 to estimate Trees Outside Forest (TOF) is such an initiative in the country. A comprehensive exercise to count trees in all cities and towns in Gujarat in 2011 is another landmark initiative. In an era of rapid urbanization, increasing air pollution and global warming, there is a need of social awareness campaign for the governance of urban systems that work for improving tree cover in cities and towns. To assess the present tree cover and the status of environment, it is necessary to estimate population of different tree species in cities and towns. Such exercises were done in the western countries, including USA to monitor the environment of the major cities. The Social Forestry Wing of Gujarat Forest Department decided to conduct total tree counting in all municipal corporations and municipalities in Gujarat state in the late 2010. The meetings of the field official were held and guidelines were issued. In Ahmedabad, the Municipal Corporation Authority also joined hand in this exercise. The district level forest officers formed enumeration teams and conducted training for collection of data. The total tree counting within boundaries of municipal corporations and municipalities were done during 2011. The period of the counting was not fixed and it was done during different periods, depending on availability of the time from their normal duty. The tree counting in the state started in 2011 but was completed in some municipal corporations and municipalities in December 2011. Although verification of counting was done in the late 2011 and also in January/February 2012, there may be possibility of minor error in some municipalities due to the absence of boundary demarcations on the ground. I hope that this document is first of its kind for urban areas in the country and may set a trend for similar exercise in other parts of the country.

Dr. H. S. Singh, IFS

Addl. Principal Chief Conservator of Forest
Social Forestry, Gujarat State

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Status of Tree Cover in the Urban Areas in Gujarat State

1. About Gujarat

On May 1, 1960, Gujarat was created out of 17 northern districts of the former state of Bombay. At present, the State has 26 districts (226 *talukas*, 18,618 villages, 242 towns). Located on the western coast of India, Gujarat has two gulfs and the longest coastline of over 1,600 Km. Gandhinagar, the capital city of Gujarat is located close to Amdavad (Ahmedabad), the commercial capital. Gujarat has total population of 6.03 crore, which is approximately 4.99% of total Indian population (Census data 2011).

For the first time since Independence, the absolute increase in Indian population is more in urban areas than in rural areas. Urban population in the country increased from 27.81 % in 2001 Census to 31.16 % in 2011 census in India. On other hands, the proportion of rural population declined from 72.19 % to 68.84 %.

Urban Population of Gujarat State is 42.6 %, which used to be at 37.4% in 2001. This has resulted into tremendous pressure on the urban resources, including urban forest, tree cover and lakes. Ahmedabad is the most populated district (city+ rural) in the State, with 72.0 lakh million people, followed by Surat with 60.7 lakh people, as per Gujarat's Directorate of census operations². The four cities-Ahmedabad, Surat, Vadodara and Rajkot are mega cities, each having population over million people and the two of them-Ahmedabad and Surat jointly have about ten million people. Each of the rest of municipal corporations and municipalities have human population below one million. Towns and industrial areas are growing fast in the coastal region. After Tamil Nadu and Maharashtra, urbanization is highest in Gujarat in India.



Dense tree cover between kankaria lake and Ahmedabad zoo

2. Tree Cover and Urban Environment

A century ago, in the beginning of 20th century, just about one tenth of the global population was living in the cities which now exceeds 50 percent and expected to increase further in future¹. The urban areas in the world account for over three fourth of Carbon emission, sixty per cent residential water and about three fourth of industrial wood consumption. In an era of rapid urbanization, increasing air pollution and global temperature, there is a need of social awareness campaign for the governance of urban systems that counter the menace of defacement of green patches of tree cover and sensitization issues of environment, hygiene, sanitation and solid waste management. Such governance is now essential in the cities and towns of Gujarat where a large number of people are living in Municipal Corporations (*Mahanagar Palikas*), municipalities (*Nagarpalikas*) which cover about 1.77% of the geographical area of the state against about 3% earth's urbanized terrestrial surface in the world¹. Compared to other parts of the world, especially India, the urbanization in Gujarat is relatively at a faster rate during the recent years. In the background of growing environmental problems in cities, both policy and science now emphasize the critical necessity of green urban areas.

According to the 2011 census, the urban population has increased to 42.6 per cent (2.57 crores) of the state's total; from 28.1 percent in 1971 (31.1 per cent in 1981, 34.49 per cent in 1991)². With the present trend, forecasts suggest that, by 2021, 3.5 crore people constituting nearly half of the state population would be residing in urban Gujarat². On the other hand, the environment capital, including tree cover and quality of air is degrading due to crowding of people, although several initiatives have been taken to halt such degradation, yet much more is needed.

Urban areas do not have only local environmental impacts but also large ecological footprints. The urbanization have variety of impacts: conversion of agricultural or forest land for urban uses and infrastructure, polluting or reclaiming of wetlands, increasing impervious cover on earth surface, quarrying and excavation of sand, gravel and building materials in large quantities and cutting of trees. The use of biomass fuel or hydro-carbon also causes indoor and outdoor air pollution. Other effects such as pollution of waterways, lakes and ground waters by untreated effluent are increasing in all urban areas. Air pollution from cities has an impact on residents' health as well as on vegetation and soils at a considerable distance. Urban transport contributes to air pollution, and the large concentration of automobiles and industries in cities causes the lion's share of urban global greenhouse gas emissions.

The most explosive urban growth is expected in Asia which is likely to have the largest urban population in the world. As the bulk of world's population shifts from rural to urban areas, poverty is becoming an increasingly urban phenomenon¹. It has been projected that within a short period, more people may live in the cities than in rural areas in Asia and this situation may reach in a decade in Gujarat. Urban areas in the developing countries have multi-faceted problems like paucity of safe water, inadequate waste management, pollution hazards, occupation and degradation of sensitive lands, flooding, poor oxygen level and inadequate green cover.

Trees are an important part of the urban landscape. They play a role in improving air and water quality and provides so many environmental and social benefits³. Trees are on the job twenty four hours every day working for all of us to improve our environment and quality of life. Besides the cooling effect, the vegetation cover improves the urban environment by reducing pollution and suspended particle matter. In

other words, trees are major environment capital assets in cities that require care and maintenance. The majority of the cities in the western world have patches of forest or blocks of tree plantations in addition to adequate number of trees along streets and in gardens. In Gujarat, Gandhinagar and Bhavnagar have such patches of forest which ameliorate the urban environment and provide recreational value to the people.

Carbon store and sequestration: Urban areas in the world account over three fourth of Carbon emission and a significant source of pollution¹. Expanding developmental activities such as industries, constructions, transports, vehicles and power plants in cities are causing a serious pollution³. As a result, the quality of air has become matter of concern for human health. Several new cities in the country like Gandhinagar in Gujarat and Chandigarh have been developed in a planned manner after developing tree cover in the town planning areas. In a few other cities, tree cover dominates over the concrete jungle but situation is reverse in majority of the cities. The concrete jungles with negligible tree cover have a high level of pollution. People in such cities have poor quality of life due to the presence of harmful gases and dust particles, and very high temperature during summers. To reduce net emission of Carbon gases, forest or tree covers in the urban area are considered a main source of Carbon sequestration. There are several cities in the world where tree cover provides services to reduce Carbon gases by sequestering it. For example, about 14.7 lakh trees in Portland's city, Oregon, USA reduce 2.4 crore kg of Carbon annually⁴. Similarly, over two lakh tone Carbon is stored in 24 lakh trees in the central part of Beijing, China where the average size of trees is small. The Carbon store and sequestration have increased during the recent year due to increase in tree cover in Beijing⁵.

The carbon store in the tree cover in the Capital city of Gujarat, Gandhinagar may be about 1.79 lakh tones. The Carbon sequestration rates are high in large trees and it is up to 90 times greater for healthy large trees than healthy small trees. In Chicago's urban forest, the average annual carbon sequestration by individual trees ranged from 1.0 kg/yr for a tree less than 8 cm in trunk diameter to 93 kg/yr for a tree greater than 77 cm⁶.

The Green India Mission (GIM), one of the missions under India's National Action Plan on Climate Change (NAPCC), hopes to sequester 4.3 crore tones of greenhouse gases each year by 2020 and absorb 6.35 percent of annual emissions. This action plan mentions about enhancing tree cover in over 2 lakh hectares in urban and peri-urban areas. It has been estimated that about 2.21 percent of the carbon stocks are stored in through urban tree cover, and the mission will promote greening forest patches threatened by expanding urban development, diffused planting and planting on institutional lands. The carbon enhancement is estimated about 2.2 lakh tones per year. This programme includes urban areas in Gujarat also. Thus, development of urban forestry may result into one tenth of above enhancement in Gujarat (MoEF, 2011)⁷.

Temperature moderation: Concrete structures absorb heat, increase temperature of the structures and radiate heat, which increases air temperature during the summer. The vegetation absorbs heat and use light in photosynthesis, reducing the availability of the sunlight that amount heating atmosphere and the local areas. In summer, temperature of Gandhinagar remains below the temperature normally recorded in Ahmedabad at same time. Tree canopies normally reduce air temperatures significantly³. A study in the United States of America reports

that trees help to lower air temperatures and the urban heat island affect in urban areas. This reduction of temperature not only lowers energy use, it also improves air quality. It has been found that large shade trees can reduce local ambient temperatures by 3 to 5 °C and the maximum mid-day temperature reductions due to trees range from 0.04 °C to 0.2 °C per 1% canopy cover increase. In Sacramento County, California, it was estimated that doubling the canopy cover to five million trees would reduce summer temperatures by 3 degree⁸.

Air pollution reduction: As cities struggle to comply with air quality standards, the trees help to clean air in more than one ways. The most serious pollutants in the urban atmosphere are Carbon gases, nitrogen oxides, sulfuric oxides and particulate pollution. Ground-level smog is created by chemical reactions between volatile organic compounds (VOCs) in the presence of sunlight. High temperatures increase the rate of this reaction. Vehicle emissions, emissions from industrial facilities, power plants and chemical solvents are the major sources of oxides of Nitrogen, volatile organic compounds and dust particles. Particulate pollution or particulate matter is made up of microscopic solids or liquid droplets that can be inhaled and retained in lung tissue causing serious health problems. Most particulate pollution begins as smoke or diesel soot and can cause serious health risk to people with heart and lung diseases and irritation to healthy citizens. Trees are important, cost-effective solution for reducing pollution and improving air quality. Leaf stomata, the pores on the leaf surface, take in polluting gases which are then absorbed by water inside the leaf. Some species of trees are more susceptible to the uptake of pollution, which can negatively affect plant growth. Ideally, trees should be selected that take in higher quantities of polluting gases

and are resistant to the negative effects they can cause^{1,3}. A study reveals that 14.7 lakh trees in Portland's city, Oregon, USA remove 9 lakh kg of pollutants annually⁴.

Trees intercept particulate matter: In addition to the uptake of harmful gases, trees also act as filters intercepting airborne particles and reducing the amount of harmful particulate matter. The particles are captured by the surface area of the tree and its foliage. These particles temporarily rest on the surface of the tree, as they can be washed off by rainwater, blown off by high winds, or fall to the ground with a dropped leaf. Although trees are only a temporary host to particulate matter, if they did not exist, the temporarily-housed particulate matter would remain airborne and harmful to humans. Increased tree cover will increase the amount of particulate matter intercepted from the air. Large evergreen trees with dense foliage collect the most particulate matter. Large healthy trees greater than 77 cm in trunk diameter remove approximately 70 times more air pollution annually (1.4 kg/yr) than small healthy trees less than 10 cm in diameter (0.02 kg/yr)^{9,10}. Based on a study, it was found that 24 lakh trees in the central part of Beijing removed 1261.4 tones of pollutants from the air in 2002. The air pollutant that was most reduced was PM₁₀ (particulate matters with an aerodynamic diameter smaller than 10 µm), the reduction amounted to 772 tons⁵. Urban forestry aims to address issue of particulate matter by campaigning for a strategy of green city^{9,10}.

Urban biodiversity conservation: Trees in cities and towns, whether on streets, in woodland or in parks, gardens, schools or hospitals, provide a wealth of benefits relating to biodiversity. They are unique in their ability to support a great variety of wildlife in some of the harshest

locations in our urban areas. The national bird-peacock uses these trees for resting at night. Raptors such as kite and vulture do nesting on these trees. Trees and shrubs provide nesting sites and food for birds and other animals. Urban trees, shrubs and wildlife help people to maintain their connection with nature.

The urban forest is expected to play its part in biodiversity conservation. Biodiversity is increasingly stressed in urban forests where selected forest species in urban area may serve as a form of ex-situ conservation. Quite often botanical gardens, located in the urban areas have a richness of biodiversity. Indroda Park in Gandhinagar with botanical garden and city forest support rich diversity of birds, including nesting of several species. Bird watching is important activity for nature lovers and youths in the Indroda Park. In several old cities, the oldest trees, and also the ones with the largest diameter are conserved in the botanical garden and not in the rural forests. Although urban forests may contain less biological diversity than rural woodlands, the animals that occur in the urban forests are still numerous. On a larger scale urban forests can create or restore biological diversity that will reconnect a city to its surrounding bioregion. Suburban wetlands-ponds and lake can be some of the most productive natural ecosystems. The cities and sub-urban areas in Gujarat are known for wetlands and they can be transformed into green space with water-bodies for recreation and biodiversity conservation. Wetlands around Ahmedabad are important breeding ground for the largest crane-Indian sarus. Greenbelts and greenways can serve as biological corridors.

Human health and tree cover: The tree cover reduces stress, and is seen to benefit the health of urban people. The shade of trees and other urban green spaces make place for people to meet and socialize and play. People appreciate watching, feeding, photographing, and painting urban wildlife and the environment they live in. Poor open space and greenery increases air pollution that triggers respiratory and

other problems, besides raising temperature, affecting biodiversity and causing psychosomatic disorders among citizens.

Recreational values: Urban green space-garden and parks, forests, tree groves and botanical gardens have significant amenity, recreational and educational value. Recreational and educational values of Indroda Nature Park, Gandhinagar and Victoria Park, Bhavnagar are immense and there is no such ecological and economic tool to evaluate annual contribution of such parks. A study in Chandigarh estimated that total annual recreational value of the city's park, garden, green avenue, forest and wildlife was about Rs. 12.0 crore¹¹.

Urban land in the United States currently occupies about 2.8 crore hectare with an estimated average tree crown cover of 27.1 %. This structure suggests that the current total urban forest carbon sequestration in the United States is approximately 70.4 crore tones with an estimated annual net Carbon sequestration of around 2.28 crore tones. Besides directly storing carbon, urban trees also reduce Carbon dioxide (CO₂) emissions by cooling ambient air and allowing residents to minimize annual heating and cooling^{12,13}. There are 5.83 lakh people and 14.7 lakh trees in Portland city, Oregon, USA and the tree canopy cover is about 26 % of the total city area of 342 km² and tree density of about 43 trees/ha⁴. The annual environmental benefits provided by the entire urban forest canopy cover exceed \$ 3.8 crore in Portland⁴.

About 19.2 lakh trees in Washington, D.C. cover 28.6 percent of the area. The urban forest currently store about 526,000 tons of carbon valued at \$9.7 million. In addition, these trees remove about 16,200 tons of Carbon per year (\$299,000 per year) and about 540 tones of air pollution per year (\$2.5 million per year). The structural or compensatory value is estimated

at \$3.6 billion. Information on the structure and functions of the urban forest can be used to improve and augment support for urban forest management programmes and to integrate urban forests within plans to improve environmental quality in the Washington, D.C. area^{12,13}.

Tree planting has been proposed by the municipal government as a measure to reduce air pollution in Beijing, the capital of China¹⁴. China accepted that urban forest is a kind of infrastructure and promoted urban forestry. The Shanghai government started to rent out land for urban forestry purposes to private companies based on a contract. According to the contract between the government and a company, 60% of the land rented by the company must be used to grow forest, and the remaining 40% can be used for establishing a tree seedling and flowers nursery which can bring commercial benefit to the company within a short period of time. In addition, in order to support private companies in establishing urban forests, the government

also provides certain economic supplements to the companies according to the area of the land rented. After 10 years, the government gets these forests back from the companies. In this way, the government solves the issue of a shortage of funds¹⁵.

The Government realizes that the tree cover can play a key role in ameliorating and maintaining the healthy environment in city. FRI, Dehradun has estimated in a study that one hectare of woodland (about 1,000 trees) absorbs 3.7 tones of carbon dioxide from atmosphere and gives out 2.5 tones of oxygen per day. A full grown Peepal tree (*Ficus religiosa*), for instance, is estimated to give 600 kg of oxygen in 24 hours¹⁶.

3. Tree Cover in Urban Areas

In majority of the urban areas throughout the world, the tree cover is declining and impervious cover is increasing due to the demand of the land for development. Amongst all the capitals of the states, Gandhinagar, Bangalore, Chandigadh, New Delhi, Guwahati, Dehradun,



Tree cover in Gandhinagar city-houses and office buildings have adequate tree cover

Bhubaneswar, and Shillong area few green cities of India which have a good tree cover and natural environment⁵. Nagpur, Thiruvantipuram and Jamshedpur also claim to be the green cities in the country. Some of these cities look very beautiful due to lush green premises all around and also due to use of natural gas vehicle or CNG to reduce the pollution. The planned development of these cities present a picture of cities that are very clean and green with trees, plants, lakes and parks. Indian cities, particularly cities and towns in Gujarat are growing at very fast pace in terms of urbanization, technology, infrastructure, and environment. However, recent rate of urbanization is adversely affecting the green cover in the urban areas.

Despite economic development, growth of population is accompanied by growth of slum and a large poverty stricken people. In the scenario of deprivation greenery in the country, the deprived sections are most affected by the pollution, rise in temperature and degradation of environment. Cities of Gujarat are urbanizing at fast pace present no different picture. Even Gandhinagar that is amongst the greenest cities of India and Vadodara known for its green cover are suffering and the green cover in these cities need urgent attention.

There is no authentic information that ranks the green cities of the world. The cities like Atlanta in USA, Islamabad in Pakistan are normally mentioned as green cities having a good tree cover. The capital city of Gujarat is also mentioned about its greenery and extent of tree population, but in the absence of comparability of data, it may not be appropriate to name any city as the greenest city of the world. While there is a need to increase green cover in urban area, a recent study conducted by the U.S.A. Forest Service reported that some four million trees are disappearing from urban areas in the U.S. each year. After examining forest and tree

coverage in 20 metropolitan areas in the USA, researchers determined that nearly all were shedding trees, and most were replacing them with impervious cover like building, roads, concrete layer over earth surface. Of the major cities studied in the USA, the tree cover ranged from a high of 53.9 percent in Atlanta to a low of 9.6 percent in Denver while total impervious cover varied from 61.1 percent in New York City to 17.7 percent in Nashville^{12,13}. The report mentions that the city tree cover was reduced, on average by about 0.27 percent/yr, while impervious surfaces increased at an average rate of about 0.31 percent/yr. In Japan, the average of tree crown coverage was 26.74% in the urban and sub-urban areas¹⁷. It could be inferred that the total urban, suburban residential or open space area of Japan is about 1,713km². In India, only Gandhinagar city in Gujarat is comparable with the green city-Atlanta in the USA or other such green city in the world.

Present green open space in South East Asian capital cities varies considerably. Green space has been defined as any piece of land covered with vegetation and usually refers to tree cover, tree groves, forest, parks, golf courses, sports fields and other open land within the built-up area, whether publicly accessible or not²². Some green cities have 20 to 30 percent of the total geographical area of the city under green cover, or 15 to 25 square meter (m²) of urban green open space per capita, based on population pressure. A substantial part of this is under tree or forest cover. Other researchers have demonstrated a case for up to 60 m² per capita of green open space in an effort to retain environmental sustainability^{1, 18, 22}. World Health Organization suggests ensuring at least a minimum availability of 9 m² green open space per city dweller. The experts in Germany, Japan and other countries proposed a standard of 40 square meters (m²) urban green space in high

quality or 140 m² suburb forest area per capita for reaching a balance between carbon dioxide and oxygen, to meet the ecological balance of human well-being¹. Currently, developed countries have tended to adopt a general standard of green space of minimum 20 m² park area or tree cover per capita. But it is difficult to achieve this norm in the big cities in Asia and India. Estimates on urban green spaces/ woodland cover in the cities of different regions in the world have been mentioned in some reports.

Tree cover and city forest are more important than parks and garden to address certain environmental problems. Several cities in Asia have planned to improve tree and green space. The success in several cities in China is impressive. Beijing aimed to increase its green space to 40% by the year 2010 and its achievement was near the target. Manila aims to achieve a tree-to-person ratio of one to four²². In India, success in Delhi is appreciable, as tree cover and garden have improved during the last decade. The developed countries have more green space whereas availability of tree cover is poor in the Asian countries, including China. During the last few decades, serious works were done in the cities of China to improve tree cover, which is apparent from the results. The urbanization is fast in India, but except a few cities, adequate care has not been taken to improve tree cover. Development of parks and forest patches in

Delhi during the last two decades is interesting, as green cover and green space improved in the area. Cities of Delhi, Chandigarh, Bangalore, Bhopal have a good number of parks, gardens, lakes and forest patches but several other cities have unplanned development.

As discussed, the following benefits of urban trees should be considered in the urban development planning.

- (i) Amelioration of urban climate extremes
Mitigation of urban heat islands and moderation of temperature in summer
- (ii) Store and sequester carbon
- (iii) Provide shelter to poor people during summer
- (iv) Intercepting airborne particles and reducing the amount of harmful particulate matter
- (v) Reduce noise pollution
- (vi) Improve air quality and reduce impact of dusty winds or cyclones
- (vii) Reduce consumption of electricity for heating and cooling
- (viii) Aesthetic contribution, scenic beauty, visual amenity
- (ix) Improve property value, and general livability and quality of urban life
- (xi) Contribute to human health and relaxation, reduce stress and anxiety levels
- (xii) Improves urban bio-diversity, especially bird's life



| Region/country/city | Estimated size of urban green space/woodland resource |
|------------------------------|--|
| Urban area in USA | Average tree cover of the urban areas in USA is 27.1 % of the geographical area and 20 major cities have average tree cover of 26.4% of geographical area ^{12,13} . |
| Washington, D.C (USA) | About 1,928,000 trees in the urban area cover 28.6 percent of the area ^{12,13} . |
| Europe | Average woodland cover of 18.5% of the geographical area within municipal limits of 26 large European cities (average tree cover-104 m ² /inhabitant) ^{1,18} . |
| Paris (France) | About 80 m ² of urban forest per inhabitant in Greater Paris region ^{1,18} . |
| Great Britain | Green areas cover about 14% of urban areas with 120,000 ha of parks/gardens space ^{1,18} . |
| The Netherlands | Average green space cover is about 19 % for 22 largest Dutch cities (about 228 m ² /inhabitant) ^{1,18} . |
| Canberra (Australia) | Estimated crown cover of about 2400 ha (about 80 m ² /inhabitant) ^{18,22} . |
| Melbourne (Australia) | Green space 40 % and tree cover-16.3 m ² /inhabitant in 1997 ²² . |
| Wellington (New Zealand) | Estimated green space is 200 m ² /person, despite the pressure of development. |
| Hong Kong | Average green space cover is about 1.81%, i.e., about 3 m ² /inhabitant ^{1,18} . |
| Urban areas in China | In 439 cities in China in 1991, the overall green space was 380,000 ha or 20.1% of the urban area. Some 40% of the cities had more than 30% green cover in 1991 ^{13,18} . In 1986, the green space coverage and public green area per capita were 16.9%, and 3.5 m ² , respectively which increased to 23.0%, and 6.52 m ² by 2000 ^{1,14,18,19} , and further increased to 32.5% of the urban area by the end of 2006 ^{1,14,18,19} , but target is expand green space upto 40%. |
| Singapore | Average green space (including public park and garden) cover is about 17.8%, i.e., 7.5 m ² per inhabitant ²² . |
| Seoul (South Korea) | Green space cover-25,2% and green space 14.57 m ² /inhabitant in 1996 ²² . |
| Kuala Lumpur (Malaysia) | Green cover 5% and green space-2.25 m ² /inhabitant in 1998. |
| Colombo (Sri Lanka) | Green space-4.4% of the geographical area ²² . |
| Jaipur (India) | Mean green space in the major Indian cities is very less. Per capita open space is 16.6 m ² in Jaipur. It has been proposed to enhance open and green space to 8.6m ² by developing green belt adjoining the city ^{1,18} . |
| Delhi (India) | Average tree and forest cover is about 11.9% of geographical area (Forest and tree cover-about 16.1 m ² /inhabitant) (FSI, 2011) ²⁰ . |
| Chandigarh (India) | Average tree/forest cover is about 14.9 % of the city area (Forest and tree cover-about 17.7 m ² /inhabitant and it is more when green open space of the parks and garden is accounted) (FSI 2011) ²⁰ |
| Gandhinagar (Gujarat, India) | Tree and forest cover of the city is 3,075 ha-53.9% of geographical area. (Forest and tree cover-about 148 m ² /inhabitant) (Forest Department 2011) ²¹ . |
| Bangalore (Karnataka, India) | Estimated tree crown cover of city is about 19.9% of geographical area (about 16.8 m ² /inhabitant) ^{18,23} . |

4. Tree Cover in Urban Areas in India

The Delhi-based National Institute of Environment Studies (NIES) prepared a list of major cities with tree cover and mentioned that Calcutta has the lowest green cover (less than one per cent of geographical area) among all mega cities²³. The NIES estimated a tree cover of 8.60 per cent in Bangalore; 11.9 per cent in New Delhi; 6.20 per cent in Greater Mumbai; and 7.5 per cent in Chennai. According to the norms, mentioned by the NIES and some other literature, the tree cover should be at least 15 per cent for megacities with a million-plus population²³. Thus, majority of the cities, including the green cities, in India have tree cover below the minimum optimum norm. Due to lack of space and demand of the land for other purpose, it may be difficult to achieve the tree cover of 15% of city area or 20 m² per inhabitants in the megacities like Ahmedabad and Surat. In such cities, the goal of achieving tree cover of 10 % of the geographical area or 10-15 m² tree cover per inhabitant may be a realistic target.

Like the Chinese Government, Delhi Government has done commendable job to expand forest and park garden before the Common Wealth Games 2010. At present 20% of Delhi's geographical area is under green cover (11.9% under tree cover and the rest under garden and parks with grasses), making per capita green space availability to around 21.43 m². Municipal Corporation of Delhi

(MCD), New Delhi Municipal Council (NDMC) and Delhi Development Authority (DDA) have many parks, city forests, biodiversity parks and other green belts. There are nine city forests and two biodiversity parks in Delhi. Nine more city forests are planned to be created. Still there is a need to identify vacant areas which can be put under the green cover. Entire ridge area (about 6,000 ha) needs to be greened.

The status about the tree cover for different cities in India is not available, but the Forest Survey of India (2011)²⁰ reported forest and tree cover in the two Urban Areas (Chandigarh and Delhi) of the Union Territories. The Gujarat Forest Department conducted a separate study (2011)²¹ to assess tree cover in Gandhinagar Town Planning Area, and the comparable figures have been given in Table-1.

In Gujarat, about 26.9 crore trees (TOF) have tree cover of 7837 sq. km., i. e 343 trees equivalent to one hectare of tree cover. A study based on remote sensing data has estimated tree cover over an area of 3,075 ha in Gandhinagar which is equivalent to 8.67 lakh trees (both estimates are of the year 2011). Thus, about 282 trees, distributed in the different girth classes above 10 cm, may be equivalent to one hectare of tree cover in Gujarat. Since trees having lower girth classes are relatively less and majority belong to medium and large size trees, this equation appears logical. The calculations regarding tree cover in the cities presented in this report are based on this equation. Sacramento's urban forest USA) has 13% tree cover which is equivalent to 73 trees/ha²⁶.

Table-1: Tree and forest cover in the urban areas of Delhi, Chandigarh and Gandhinagar

| Name of city | Total geographical area (sq. km.) | Forest and tree cover (sq. km.) | | Total tree and forest cover (sq. km) | Percent of geographical area |
|--------------|-----------------------------------|---------------------------------|------|--------------------------------------|------------------------------|
| | | Dense | open | | |
| Delhi | 1,483 | 56 | 120 | 177 | 11.9% |
| Chandigarh | 114 | 11 | 6 | 17 | 14.9% |
| Gandhinagar | 57 | 21 | 10 | 31 | 53.9% |

Source : FSI, Dehradun (2011)

Role of parks and gardens has become much more important in view of ever-increasing population of cities, particularly in developing countries. Tangible and intangible benefits provided by these green parks and patches of tree covers are often taken for granted. Like other developing economies, India is getting urbanized at a faster pace. Generally, cities of developing countries have lower per capita availability of urban green spaces in comparison to the developed countries¹. Urban forestry studies, involving technical and social science aspects are lacking in developing countries, including India. From the global perspective, although there are wide variations both in coverage as well as per capita availability of green spaces, cities renowned for their fairly good urban green spaces often have 20 m² urban green space per capita. Most of the Indian cities, with the exceptions of Gandhinagar and Chandigarh, are far behind in per capita urban forest and tree cover availability in comparison to European, Australian and USA and Chinese cities.



Plantation in different sectors in Gandhinagar



Multi-row street plantation

5. Initiative of Gujarat State

Tree plantation in cities and town has been practiced throughout the state. First planned urban afforestation in Gujarat was done in Gandhinagar, after a decision of the Government to develop Gandhinagar as the Capital of the state. The Forest Department was first to step in to start tree plantation in a planned manner in mid 1960s. Ravines and other areas around Sabarmati River were planted. Road sites dividing the sectors were also planted. Subsequently, open areas of the sectors were also afforested. From 1971 to 2011, a total area of 25,180 ha was afforested by planting over 34.95 lakh seedlings¹⁸.

Van Mahotsav was celebrated in all towns and cities. The park and garden wings of the municipalities carried out tree plantation. In 2005, Gujarat Urban Development Mission (GUDM) of the Urban Department and Forest Department took another initiative to start *Nagar Nandan Van* Yojana. The plan for 129 municipal corporations and municipal areas were approved in 2005-06 to plant 8.34 lakh tall seedlings and also to distribute about 6.33 lakh seedlings to people²¹. This programme helped to improve tree cover in several towns in state. The *Nagar Nandan Yojan* has been

one of the successful afforestation programme to improve urban ecology and environment. Subsequently, this plan was extended to more towns but has been discontinued, after expiry of the project period. The Urban Department also implemented plantation schemes separately to improve greenery in the cities. Tree plantations in campaign mod were also carried out in some cities such as Amdabad, Surat and Vadodara.

Through notification of the Gujarat Urban Development Department in November 2009, the Government emphasized Urban Green Plan to improve tree cover. The provision for creation of *Panchavati, Smriti Van, Sanskritic Van, Oxygen park, green guard* etc have been made to involve people, NGOs and civic society to plant trees in the open space. The notification also mentions plantation of at least ten trees by every section of classes in schools. Urban Authorities are advised to earmark certain percent of budget for raising trees.

Gujarat State initiated a programme to establish cultural forest (*Sanskritic Van*) near urban and sub-urban centre in 2004 during celebration of state level *Van Mahotsav*. *Punit Van* was established at Gandhinagar in 2004, *Mangalya Van* at Ambaji in 2005, *Tirthankar Van* at Taranga in 2006, *Harihar Van* at Somnath in 2007, *Bhakti Van* at Chotila in 2008, *Shyamal Van* at Shamlaji



Punit Van at Gandhinagar

in 2009, *Pawak Van* at Palitana in 2010, and *Virasat Van* at Pawagadh in 2011. To connect people with plantation and protection of trees various cultural forests such as *Nakshatra Van*, *Rashi Van*, *Panchavati*, *Ashok Van*, *Dhanvantri Van*, *Smruti Van* etc. have been created at the sites. These cultural forests have become important recreational and educational areas for people and add environmental values to the urban area. Urban Authorities also established such forest at several sites.

6. Tree counting in Urban Areas in Gujarat

The State government has constituted 8 Municipal Corporations, 6 Urban Development Authorities, 10 Area Development Authorities and 159 Municipalities. Also, 99 Municipalities are designated as area development authorities as well as 15 *Gram Panchayats* are also designated as area development authorities for planning urban development in the state (Department of Urban Development, 2011).

Tree survey to estimate tree population in the rural areas, outside the forests in Gujarat were done in 2003 and 2009, but no such assessment was done for the urban areas-cities and towns in the state. First time tree counting in all *Mahanagar Palikas* (Municipal Corporations)

areas and *Nagar Palikas* (Municipalities) areas was done in 2011 by the Social Forestry Wing of the Gujarat Forest Department with active participation of local institutions. The tree cover has also been estimated for the villages around the municipal corporations in the area of urban development authorities. The tree cover has been assessed in Gandhinagar at intervals. The objectives of the urban tree census were as follows.

- (i) To estimate the total number of trees and status of tree cover in the urban areas in the state.
- (ii) To create a baseline information to monitor trend of tree cover in different cities in the state.
- (iii) To find out the preferences of tree species in urban areas in different zone and also to use such information for planning urban forestry.
- (iv) To assess changes/progress in tree cover in future.
- (v) To assess Carbon store and also scope of Carbon sequestration in the urban areas.
- (v) To develop plan for improving environment of the cities and towns.



Some old houses has very good tree cover

7. Planning and Methodology

As discussed above, tree counting was done in the rural area but such exercise was never done in the urban areas in the past. To assess the present tree cover and the status of environment, it is necessary to estimate population of different tree species in the cities and towns. Such exercises were done in the western countries, including USA to monitor the environment of the major cities. The Social Forestry Wing of Gujarat Forest Department joined hands with Urban Department to plant trees in cities and towns in Gujarat. Subsequently the Social Forestry Wing of the department decided in the late 2010 to conduct total tree counting in all municipal corporations and municipalities in Gujarat State. For future planning, the areas under urban development authorities of the Municipal Corporations were also included to estimate the tree population. Within boundaries of municipal corporations (*Mahanagar Palikas*) and municipalities (*Nagarपालikas*), all trees standing in the parks and garden; compounds of school, colleges and institution; along streets and roads; cantonment area; forest lands; individual premises and any other such areas were counted. In other words, hundred percent enumeration of trees was done in different diameter classes within boundaries of the *Mahanagar Palikas* and *Nagarपालikas*. In the area of Urban Development Authority, tree counting was done in randomly selected villages and the data was projected to estimate the tree population. The first planning for tree counting in urban areas of Gujarat was done in the late 2010 and enumerations were completed during the year, 2011, and verification of counting was done in the late 2011 and also in January 2012.

Social Forestry Wing of the Forest Department planned and coordinated tree census in the urban areas in the state. The regional heads of the social forestry circles had coordinated tree counting in the circles (zones). The counting in cities at district level was organized and

conducted by the Dy Conservator of Forests, Social Forestry whereas Assistant Conservator of Forest and Range Forest Officers coordinated and conducted tree counting in municipalities (*Nagarपालikas*). The teams for each *Mahanagar Palikas* and *Nagarपालikas* were constituted and they were guided and trained about the methodology to count and measure the girth of the trees. In this counting, the trees having girth at breast height (GBH) above 10 cm were counted. In certain cities, municipalities and educational institutions also joined hands with the forest department in this exercise. In Ahmedabad Municipal Corporation area, the Forest Department counted trees in cantonment and other areas, teachers and students organised counting in the compounds of schools and institutions, and park warden department of the Municipal Corporation counted in parks and other such areas. In Ahmedabad, the Municipal Corporation collected data and compiled result. But in other municipal corporations and municipalities, the Social Forestry Divisions analysed data and prepared the tree census report. In this census, trees of each species were counted in the eleven girth classes (10 to 30 cm, 30⁺ to 45 cm, 45⁺ to 60 cm, 60⁺ to 75 , 75⁺ to 90 cm, 90⁺ to 120 cm, 120⁺ to 150 cm, 150⁺ to 200cm, 200⁺ to 250 cm. 250⁺ to 300 cm and above 300 cm.). Tall sapling, even more than two meter, having GBH less than 10 cm were not counted.

Tree cover in Gandhinagar was also assessed using remote sensing data. The results of tree cover and tree population in Gandhinagar helped to develop an equation between tree cover and number of trees.

8. Status of tree cover in Municipal Corporation Areas

Tree counting data reveal that Gandhinagar is the greenest city in the terms of tree density as well as the area under tree cover. Over all, Gandhinagar, Bhavnagar and Vadodara may be called as green cities having tree densities higher

than the average density in the eight municipal corporations. Other municipal corporations- Surat, Ahmedabad, Rajkot, Junagadh and Jamnagar have tree densities below the average.

Table-2: Tree population in Municipal Corporation Areas - Eight major cities in Gujarat

| Mahanagar Palika | Human population | Geographical area in ha | Number of trees above 10 cm GBH | Tree density per hectare | Tree cover % of geographical area |
|------------------------------|-------------------|-------------------------|---------------------------------|--------------------------|-----------------------------------|
| 1. Ahmedabad | 5,570,590 | 46,985 | 618,048 | 13.2 | 4.66 |
| 2. Surat | 4,462,000 | 39,549 | 333,990 | 8.4 | 3.00 |
| 3. Vadodara | 1,666,700 | 16,264 | 747,193 | 45.9 | 16.29 |
| 4. Gandhinagar | 208,300 | 5,700 | 866,672 | 152.0 | 53.9 |
| 5. Rajkot | 1,287,000 | 10,400 | 137,522 | 13.2 | 4.69 |
| 6. Bhavnagar + Victoria Park | 593,770 | 5,320 | 475,953 | 89.46 | 21.35 |
| 7. Junagadh | 320,250 | 5,670 | 76,694 | 13.5 | 4.80 |
| 8. Jamnagar | 529,310 | 3,434 | 45,877 | 13.4 | 4.74 |
| Total | 14,637,920 | 133,322 | 3,301,949 | 24.8 | 9.65 |

Note: (i) Victoria Park (202 ha.), a forest area, is within Bhavnagar Municipal Areas and a total of 212,521 trees of Victoria Pak are included in the above figures. Similarly trees in about 450 ha of Indroda Park (forest area) are included in the tree population in Gandhinagar.

Table-3: The tree cover and tree cover per inhabitant

| Mahanagar Palika (Municipal Corporation) | Geographical area (in ha) | Tree cover (in ha) | Tree and forest cover per habitant | Trees per 100 persons | Number of trees to meet a minimum standard of 10m ² tree cover/ inhabitant (Lakh) |
|--|---------------------------|--------------------|------------------------------------|-----------------------|--|
| 1. Ahmedabad | 46,985 | 2,188 | 3.9 m ² | 11.08 | 15.82 |
| 2. Surat | 39,549 | 1,184 | 2.7 m ² | 7.48 | 12.37 |
| 3. Vadodara | 16,264 | 2,650 | 15.9 m ² | 44.83 | 7.47 |
| 4. Gandhinagar | 5,700 | 3,075 | 147.6 m ² | 416.07 | 8.67 |
| 5. Rajkot | 10,400 | 488 | 3.8 m ² | 10.69 | 3.63 |
| 6. Bhavnagar + Victoria Park | 5,320 | 1,136 | 19.1 m ² | 88.16 | 4.76 |
| 7. Junagadh | 5,670 | 272 | 8.5 m ² | 23.4 | 0.90 |
| 8. Jamnagar | 3,434 | 1,877 | 3.1 m ² | 8.66 | 1.48 |
| Total | 133,322 | 12,870 | 8.8 m² | 22.55 | 55.10 |

Note: On an average trees in cities of Gujarat are large. In above, one hectare of tree cover is equivalent to 282 trees having GBH above 10 cm. It is expected that about half of this number may be in medium to large tree category. Saplings, shrubs, woody flowering plants and bushes below the dimension of tree size (10 cm GBH), which are not accounted in trees in the tree cover, fill some space to cover the gap.

8.1 Dimension of trees

The number of trees in higher girth classes is relatively high compared to the normal distribution of trees in different girth classes. About 1.35 per cent of total trees have GBH above 200 cm. Distribution of trees in different girth classes in the area of eight municipal corporations is given in Table-4.

The salient features of the tree counting in the eight municipal corporation areas are as follows.

- (i) Eight municipal corporations support about 33.02 lakh trees whereas 159 *nagarpalikas* have 32.44 lakh trees. Thus, about 65.45 lakh trees (2.44 % of Trees Outside Forest-TOF) grow in cities and towns in Gujarat state.
- (ii) The tree cover in Gandhinagar is exceptionally high and comparable with the greenest cities in the world. Also, the two cities - Bhavnagar and Vadodara have adequate trees as the tree cover in these cities was more than the other green cities like Chandigadh and New Delhi. As per the recent report of the FSI, Dehradun and the study of the GEER, Foundation, amongst all major cities in India, tree density is highest in Gandhinagar. The green cover in other two cities-Bhavnagar and Vadodara is comparable with the major green cities in India.

- (iii) Surat has a very poor tree cover and it is far below the average.
- (iv) If tree cover norm of at least 15 percent of geographical area is applied for megacities such as Delhi and Chandigadh, the cities of Surat, Rajkot, Jamnagar, Junagadh and Amdabad have inadequate tree cover.
- (v) Average green cover in the Municipal Corporations is low. Average tree cover per inhabitant for eight Municipal Corporations is 8.8 m²/inhabitant, below the norm.
- (vi) To achieve the minimum norm of 15 % tree cover in the mega-cities, the total number of trees in eight municipal corporations should increase from about 33.01 lakh trees (9.65 % of geographical areas) to 65.71 lakh trees (minimum 15 % of geographical areas).
- (vii) The Carbon stored in the tree cover in the urban area (municipal corporations and municipalities) of Gujarat is about 13.5 lakh tones, which can be increased to about 27.6 lakh tones of Carbon, if above norm is achieved.
- (viii) If adequate space is not available in the city, intensive tree plantations may be taken in the area of Urban Area Authorities to make up the gap.

Table-4: Distribution of trees in different girth classes in the area of eight municipal corporations

| Size | Girth classes | Number of trees | Percent |
|----------------------------|---------------|------------------|--------------|
| Small size trees | 10-30 cm | 917,840 | 27.8 % |
| | 30-60 cm | 1,121,470 | 34.0 % |
| Medium size trees | 60-90 cm | 737,340 | 22.3 % |
| | 90-120 cm | 262,330 | 7.9 % |
| Medium to large size trees | 120-150 cm | 138,850 | 4.2 % |
| | 150-200 cm | 80,570 | 2.5 % |
| Large size trees | 200-300 cm | 39,130 | 1.3 % |
| Very large trees | Above 300 cm | 4,420 | |
| Total | | 3,301,950 | 100 % |

9. Status of Trees Cover in the Areas of Urban Development Authorities

Villages around the major cities-Municipal Corporations have been included in the Urban Development Zone and their development is planned by the Urban Development Authority. Few villages (over 10%) were selected randomly for tree counting and the data have been projected to estimate the tree cover in the areas of Urban Development Authorities. The tree populations in the areas of eight Urban Development Authorities have been estimated in the Table-5.

Tree cover in the villages around Gandhinagar and Vadodara is very good and it is very poor in the area of Rajkot Development Authority.

In Gujarat, it is difficult to increase tree cover beyond a limit in some of the municipal corporation areas due to non-availability of the space. The gap of tree cover can be compensated

by increasing tree cover in sub-urban and area under Urban Development Authorities.

There are several lakes/ponds in the villages around the municipal corporation areas. These wetlands should be preserved and their status should be improved by planting suitable trees like *Ficus* sp., Neem, Jamun, Rayan, Mango and Deshi babool. Some of these lakes and ponds can be developed as recreational and tourist sites by enriching areas raising suitable species of trees.

Average tree density in the rural areas of Anand district is above 68 trees/ha. Also, rural areas in Mehsana and Gandhinagar have an average tree density of above 50 trees/ha. It is possible to achieve this level of tree cover under intensive agro-forestry and horticulture programmes in the villages around the *Mahanagar Palikas*.

Table-5: Tree population and tree cover in the area of Urban Development Authorities

| Urban Development Authority | Number of villages | Area in ha | Total number of trees | Tree density per hectare |
|--|--------------------|----------------|-----------------------|--------------------------|
| AUDA (Ahmedabad Urban Development Authority) | 67 | 59,375 | 79,5470 | 13.40 |
| RUDA (Rajkot Urban Development Authority) | 54 | 56,224 | 16,6410 | 2.96 |
| VUDA (Vadodara Urban Development Authority) | 98 | 55,200 | 1,814,360 | 32.87 |
| SUDA (Surat Urban Development Authority) | 94 | 32,651 | 464,510 | 14.23 |
| BADA (Bhavnagar Urban Development Authority) | 15 | 13,147 | 180,910 | 13.76 |
| JUDA (Junagadh Urban Development Authority) | 40 | 30,722 | 369,780 | 12.04 |
| JADA (Jamnagar Urban Development Authority) | 26 | 24,142 | 308,390 | 12.77 |
| GUDA (Gandhinagar Urban Development Authority) | 39 | 38,800 | 2,260,100 | 58.25 |
| Total | 433 | 310,261 | 6,359,930 | 20.50 |

10. Status of tree cover in *Nagar Palikas*

There are a total of 159 *Nagarpalikas* (municipalities) in Gujarat State with geographical area of about 212,440 ha. Total tree counting was done in all *Nagarpalikas* in 2011. A total of 32,44,155 trees having Girth at Breast Height (GBH) above 10 cm were counted in these municipalities with average tree density of about 15.3 trees per hectare. The towns/*Nagarpalikas* in Gujarat have been classified into four categories of tree density, as given at the bottom of the page.

Salient features of the survey are given below.

- (i) Some of the *Nagarpalikas* like Kanjari, Ankleshwer, Umreth, Balasinor, Anklav, Chansava, Vallabhipur, Dakor and Porbandar have very good tree cover with density above 50 trees/ha. Tree density in Porbandar is high due to the presence of mangroves within the area of the city.
- (ii) Average tree density of all *Nagarpalikas* in Gujarat is 15.3 trees/ha, which is below the average tree density of Tees Outside Forest (TOF). The average tree cover in the *nagarpalikas* is about 5.4% of their total geographical area.
- (iii) About half of the total *Nagarpalikas* have poor tree cover, and 70 of them have tree density below 10 trees/ha. Of them, 27 *Nagarpalika* have very poor tree cover- tree density below 5 trees/ha.
- (iv) Presence of tree is extremely poor in five *Nagarpalikas*-Dhandhuka in Ahmedabad, Maliya in Rajkot, Rapar in Kachchh, Radhanpur in Patan, Tharad in Banaskantha as they have tree density below 2 trees/ha.
- (v) Sixteen *Nagarpalikas* have tree cover above 15 % of their geographical area and 52 *Nagarpalikas* have tree cover between 5% and 15% of their geographical area. The condition of the rest the *Nagarpalikas* in term of tree cover is very poor, and eight of them even do not have 1% of their geographical area under tree cover.
- (vi) The urban development areas around the *nagarpalikas* have been identified and this opportunity may be used to provide enough space of tree growth like it was done in Gandhinagar.
- (vii) About three dozen *Nagarpalikas* have tree cover above 10% of the geographical area and the rest have poor tree cover.
- (viii) To achieve at least 10 % of the *Nagarpalika* areas under tree cover, the number of trees should increase by 27.3 lakh (from 32.4 lakh trees at present to about 59.8 lakh trees).
- (ix) To achieve a target of 15% geographical areas in *Nagarpalikas* under tree cover, the population of trees should increase by 41 Lakh (from about 32.4 lakh trees at present to about 73.4 lakh).

| Tree density class | Number of <i>Nagarpalika</i> | Tree cover- percent of geographical area |
|---|------------------------------|---|
| 1. Tree density above 50 trees/ha | 8 | Above 17.7 % |
| 2. Tree density between 30 to 50 trees/ha | 23 | Between 10.6 % and 17.7 % |
| 3. Tree density between 10 to 30 trees/ha | 58 | Between 3.5 % and 10.6 % |
| 4. Tree density below 10 trees/ha | 70 | Below 10.6 % |
| Total | 159 | 5.4 % (average of all <i>Nagarpalikas</i>) |

Table-6: Tree Cover in the Urban Areas (*Mahanagar Palikas + Nagar Palikas*)

| Descriptions | Total/average of eight municipal corporations | Total of 159 municipalities | Total/average of Urban Area |
|--|---|-----------------------------|-----------------------------|
| Area (ha) | 133,322 | 212,440 | 345,762 |
| Human population | 14,637,900 | 11,062,100 | 25,700,000 |
| Tree population | 3,300,980 | 3,244,160 | 6,545,130 |
| Average tree density (trees/ha) | 24.76 | 15.27 | 18.93 |
| Tree cover (ha) | 12,870 | 11,504 | 24,374 |
| Average tree cover of total area (%) | 9.65 % | 5.42 % | 7.05 % |
| Number of trees per 100 inhabitants | 22.6 | 29.3 | 25.5 |
| Tree cover per inhabitant (m ² /inhabitant) | 8.8 m ² | 10.4 m ² | 9.5 m ² |

In Gujarat State, India, averages of 167 urban areas (8 municipal corporations and 159 municipalities) are: tree cover - 24,374 ha, tree density-18.93 trees/ha, and tree cover of the total area-7.05%. These figures are far below the standard. The tree cover per person in the urban area of Gujarat is 9.5 m², which is also far below the standard.

Many forests at the urban fringe such as Victoria Park in Bhavnagar, Indroda Park in Gandhinagar and parks and garden in Vadodara are threatened by urbanization and they need protection. This is possible when true value of such forests is accounted properly to counter the forces of urbanization. The American Forests Urban Ecosystem Analysis (Green City) offers a means of quantification of the environmental benefits of urban trees. American Forest Service has transferred Urban Ecological Analysis methods to local communities so that they can recognise, measure, and advocate better natural resource policies in their communities. Benefits include energy conservation, urban heat island reduction, storm water runoff, air pollution reduction, noise and glare control, carbon sequestering and urban recreation/enjoyment. The analysis has been developed to help local

people demonstrate the value of trees in their community to its leaders, putting tools into the hands of local people, so that they can make community-based decisions that affect long-term planning, management, and funding. This method may also be tested in several countries in the Asian region, including urban areas in Gujarat in the background of environment problem.

Developed countries and advance developing countries such as China recognized value of urban forest and they implemented plans to increase green space in the interest of quality of life. Allocation of budget for developing urban forestry has increased in many countries. Seoul in South Korea normally made a provision of 2.5 % budget of city for urban forestry. Melbourne in Australia allocates 6.5 % per cent of its budget for urban forestry²⁴. Gujarat Government has also issued direction to *Mahanagar Palika* and *Nagarpalika* to keep a provision of 6% of the budget for parks and tree plantations. Gujarat Industrial Development Corporation has also passed similar resolution to promote tree plantation in the industrial areas.

11. Tree species

Out of about 410 tree species in Gujarat, over 230 tree species were encountered during the enumeration in the urban areas of Gujarat. The main tree species in order of their number are Neem (*Azadirachta indica*), Asopalav (*Pollyalthia longifolia*), Deshi baval (*Acacia nilotica*), Gando-baval (*Prosopis chilensis*), Amaltas or Garmalo (*Casia fistula*), Peltrofurum (*Peltroforum ferruginieum*), Kasid (*Casia siamea*), Sirus (*Albizia lebbek*), Gulmohar (*Delonix regia*), Ardusa (*Ailanthus excels*), Saptparni (*Alstonia scholaris*), Pendula (*Polyalthia pendula*), *Eucalyptus* sp. *Casuarina equisetifolia*, *Prosopis chilensis*, Kanji (*Pongamia pinnata*) and, Mango (*Mangifera indica*). The number of *Ficus* species-Vad (*Ficus benghalensis*), Pipado (*Ficus tsila*) and Peepal (*Ficus religiosa*) is also good but their presence in all cities or dominance in some cities are felt due their size and dimension. The number of the main species has been given in the Table-7.

Neem is the most dominant tree in towns

and cities in North and Central Gujarat and Saurashtra. Number of *Asopalav* and *Pendula*, species planted in gardens and compounds, is high but it is not very significant in term of biomass and canopy cover. Recently, *Saptparni-Alstonia scholaris* is planted in all cities and number of this species is increasing in most.

The ten main tree species constitute more than half of the total urban tree population. There is possibility of error in differentiating *Asopalav* and *Pendula*, as in some area they are identified by same local name. Neem constitutes over 13.1 % of total trees in the urban area and, in term of biomass, its share may be much higher. Gorad occupies second position due to their dominance in the natural forests in Victoria Park, Bhavnagar and Indroda Nature Park, Gandhinagar. *Asopalav/Pendula* are common species in the garden and private compound as they occupy less space but attain a good height. Gando-baval has invaded in some areas, especially in the fringes of the cities and along river and streams. Deshi-baval is common



Gulmohar plantation

species and its presence is good in majority of the cities and towns. *Pipalo* is important species. Although number is not very high but appears dominant in some cities due its canopy dimension.

A few exotic species like Gando baval (*Prosopis chilensis*), *Eucalyptus sp.*, Su-baval, Israel baval and Saptaparni are among the twenty

dominant tree species in the urban areas. Pipal (30,890) and Vad (24,830) do not appear in the list of the main twenty species but their presence is felt, and they are dominant species in term of biomass and Carbon store values. The distribution of different tree species in different *Nagarpalika* follows the trend that prevails in the *Mahanagar Palika* of that region.

Table-7: The population of 20 major species in different municipal corporations

| Tree species | Number of trees in Mahanagar Palika | | | | | | | | |
|-----------------------|-------------------------------------|----------------|----------------|----------------|----------------|----------------|---------------|---------------|------------------|
| | A'bad | Vado-dara | Gandhi-nagar | Surat | Bhav-nagar | Rajkot | Jam-nagar | Juna-gadh | Total |
| Neem/Limdo | 142,768 | 45,439 | 172,443 | 8,167 | 30,255 | 23,547 | 6,838 | 5,321 | 434,778 |
| Gorad | 7,526 | 6 | 11,363 | 0 | 180,206 | 1 | 199 | 2 | 191,777 |
| Aso palav/ Pendula | 70,550 | 60,252 | 27,918 | 23,042 | 22,923 | 15,821 | 1,792 | 11,917 | 234,215 |
| Gando baval | 7,526 | 95,03 | 79,462 | 10,524 | 55,036 | 1,293 | 2,184 | 165 | 158,167 |
| Deshi baval | 39,540 | 12,654 | 64,849 | 8,297 | 3,253 | 623 | 1,378 | 319 | 130,913 |
| Garmado | 16,701 | 14,900 | 84,113 | 6778 | 2,071 | 1,048 | 460 | 240 | 126,311 |
| Peltoform | 18,985 | 45,401 | 26,668 | 7447 | 10,468 | 6976 | 809 | 1637 | 118,391 |
| Kasid | 20,044 | 30,009 | 39,444 | 8,661 | 4,952 | 4,631 | 883 | 739 | 109,363 |
| Gulmohar | 40,064 | 26,825 | 3,843 | 11,406 | 9,997 | 6,338 | 894 | 1,610 | 100,977 |
| Israel baval | 1,100 | 719 | 77,618 | 10 | 69 | 20 | 178 | 1 | 78,605 |
| Kanji | 41,590 | 7,518 | 24,142 | 120 | 2,416 | 662 | 110 | 52 | 76,380 |
| Saptaparni | 4,601 | 37,453 | 1,368 | 11,973 | 5,990 | 12,301 | 59 | 1805 | 70,949 |
| Nilgiri | 4,545 | 26,971 | 17,437 | 10,031 | 3,201 | 1,179 | 965 | 2,384 | 66,713 |
| Sharu | 4,200 | 22,309 | 561 | 3,770 | 3,623 | 315 | 908 | 710 | 32,196 |
| Pendula | 0 | 25,397 | 5,655 | 0 | 4,097 | 7,403 | 0 | 10,291 | 52,843 |
| Badam | 6,814 | 18,202 | 983 | 9,163 | 6,534 | 941 | 962 | 458 | 44,057 |
| Pipalo | 20,177 | 8,029 | 2,384 | 1,281 | 4,183 | 2,411 | 357 | 703 | 39,525 |
| Su-baval | 14,882 | 3,964 | 947 | 1,500 | 12,078 | 2,709 | 1,295 | 1,089 | 38,464 |
| Karanj | 3,140 | 4,434 | 9,244 | 1,342 | 11,105 | 6,960 | 1,249 | 632 | 38,106 |
| Bamboo | 1,450 | 2056 | 31775 | 587 | 788 | 46 | 93 | 68 | 35,413 |
| Total | 458,677 | 367,239 | 676,562 | 124,099 | 369148 | 87822 | 21503 | 29452 | 2,124,890 |
| Others | 159,371 | 370,559 | 190,110 | 209,873 | 106,805 | 49,700 | 24,264 | 47,242 | 1,176,085 |
| TOTAL | 618048 | 747,193 | 866,672 | 333,972 | 475,953 | 137,522 | 45,877 | 76,694 | 3,300,975 |

12. Carbon store and Carbon sequestration

In USA, the national average urban forest carbon storage density in biomass is 25.1 tC/ha, compared to 53.5 tC/ha in forest stands. In the Indian forest, as a thumb rule, one cubic meter of growing stock in the natural forest is equivalent to 1.1 tones of Carbon (including Carbon in soil)²⁶. In the TOF, only tree biomass is accounted to estimate Carbon. Thus, one cubic meter of growing stock may be equivalent to about half tone of Carbon. A statistical analysis reports that, on an average, one tree store about 181 kg of Carbon in the urban areas in USA²⁶, although it depend on the climatic and edaphic condition of the area and composition of tree species. In Washington DC, on an average, one tree store about 274 kg of Carbon¹². The rate of annual Carbon sequestration has great variation with increase in the girth of tree. For medium growing tree species, Carbon sequestration rate varies from 2.8 kg per year in about a five years old tree to 5.1 kg in ten year old, 10.5 kg in 20 years old tree, 23.5 kg in 40 years old tree and then to 37.7 kg in sixty years in city of the USA. Average Carbon sequestration per tree has been estimated about 6.8 kg in urban areas in USA, although it has great variation with change in size of trees. The Carbon sequestration rate varies from 1.0 kg/year in tree having 20 cm GBH to 93 kg/year²⁶ having 240 cm GBH. A study reveals that a good size tree of *Prosopis chilensis* store Carbon at rate of about 7.5 kg every year. The size of trees in urban areas of Gujarat is relatively higher than tree in the rural area. Average of eight municipal corporation indicates that 1.31 % of total trees have GBH over 200 cm. In Ahmedabad, about 3.70 % trees have GBH above 200 cm. This reveals that some cities in Gujarat have relatively more old trees than in the other areas.

In India, the growing stock of 506.8 crore stems of the TOF is about 154.8 crores cubic meters. In Gujarat, about 26.8 crore trees (TOF) have

growing stock of 11.8 crore cubic meter and Carbon store in biomass about 5.565 crore tones^{27,28}. The Indian Council of Forestry Research and Education, Dehradun has estimated Carbon in the forest and TOF in India. As per this norm, on an average one tree in Gujarat may store about 207 kg of Carbon against India's average of 208 kg Carbon/tree²⁷. The average size of trees in urban areas in Gujarat, particularly in Ahmedabad is higher than the average of the TOF. As a result, the figure of Carbon store may be high for trees in urban areas, particularly in Ahmedabad.

Also, as per the present growing stock, the annual potential production of timber and fuel wood in India is 4.28 crore cubic meter and 1.93 crore tones, respectively. In Gujarat, the corresponding figures are 31.0 lakh cubic meter for timber and 21.2 lakh tones for firewood. As per these data, the Carbon sequestration rate per tree may be estimated about 7.86 kg Carbon/year for the average of India. If the growing stock of the TOF in Gujarat is co-related to the number of trees (26.9 crore), the Carbon sequestration rate may be estimated about 12.91 kg Carbon/year/tree for average of the state^{26,27}. These data can be used to help assess the actual and potential role of urban forests in reducing atmospheric Carbon dioxide, a dominant greenhouse gas.

On one hand, average tree size in Ahmedabad is higher than other cities but it is lower in Bhavnagar due to a large number of small trees (*Acacia senegal*) in Victoria Park. If it is assumed that Carbon store of about 208 kg Carbon per tree in Ahmedabad and 207 kg Carbon/tree for the rest of cities, the Carbon store in different municipal corporation may be estimated about 1.79 lakh Carbon tone (6.57 lakh tone of Carbon di-oxide) for Gandhinagar, 1.28 lakh Carbon tone (4.70 lakh tones of CO₂) for Ahmedabad, 1.55 lakh Carbon tones for Vadodara, and 0.99 lakh Carbon tones for Bhavnagar and 1.22 lakh tones for the rest of other four municipal corporations.

Table-8: Carbon store and sequestration rate (Value in tones)

| Categories | Number of trees (in Lakh) | Carbon store (lakh tone Carbon) | Carbon store equivalent to absorption of CO ₂ | Annual Carbon sequestration (tone Carbon) | Annual CO ₂ absorption rate (Carbon tone) |
|---|---------------------------|---------------------------------|--|---|--|
| Municipal Corporations (8) | 33.01 | 6.83 | 25.07 | 28,066 | 103,002 |
| Municipalities (159) | 32.44 | 6.72 | 24.66 | 25,498 | 93,578 |
| Urban Development Areas of eight Municipal Corporations in 433 villages | 63.60 | 13.17 | 48.33 | 49,990 | 183,463 |
| Total | 129.05 | 26.72 | 98.06 | 103,554 | 380,043 |

Thus, total Carbon store in the trees in eight municipal corporations may be about 6.83 lakh tones (25.07 lakh tones of CO₂).

Above analysis provide information that the trees in eight municipal corporations and 159 municipalities store about 13.55 lakh tone of Carbon which may be equivalent to total absorption of 49.73 lakh tones of Carbon di-oxide. The annual Carbon di-oxide absorption rate of these trees in municipal corporations and municipalities has been estimated about 1.97 lakh tones of Carbon di-oxide. If tree population is doubled in these cities, the Carbon sequestration rate may also increase in the proportion of tree population.

Total Carbon store in trees growing in eight *Mahanagar Palika*, 159 *Nagarpalikas* and

peripheral villages of the corporations is about 26.72 lakh Carbon tones. The tree cover in urban area should be doubled under an intensive urban afforestation. If this is achieved in over a decade, the Carbon store may increase at a rate of over two lakh Carbon tone per year. This may result into reductions in energy consumption also. Other environmental benefits like energy saving, reduction in air pollution and particulate matters and human health from urban forestry might be much more than Carbon store value and annual benefits due to Carbon sequestration. Trees planted in the cities and adjacent to buildings can significantly reduce cooling and heating needs by providing shade during summer and acting as windbreaks during winter.



13. Status of tree cover in different Municipal Corporations

13.1 Trees in Gandhinagar Capital Project Area (Gandhinagar Municipal Corporation Area)

Introduction

Area of Gandhinagar Capital Project was a part of villages which lacked development in terms of agriculture and basic amenities before selection of the site for capital of a new state-Gujarat. After bi-furcation of Bombay state in 1961, the Gujarat Government started functioning from Ahmedabad. Subsequently, the Government identified the area near Ahmedabad along Sabarmati River to be named as Gandhinagar as the Capital of Gujarat. A master plan of Gandhinagar was designed and finalised after identification of area in 1966. Before this, the major part of Gandhinagar was a part of dusty ravines of Sabarmati. Tree cover was very poor, although there is no report which provides information about the status of vegetation in the area. At present, the area of Gandhinagar Capital Project is 5,700 ha and it has been divided in 30 sectors, and large areas, mostly along both sites of Sabarmati River, were demarcated separately and were excluded from development in the initial stage. Now development of institutions and offices has started in those areas also.

Plantation in Capital Project Area

Capital development works were started in 1967 and the Forest Department was entrusted the work to afforest ravines and other areas to provide a background of the green city. Subsequently, Gandhinagar Forest Division was constituted in 1973. The tree plantations were taken up in ravines, along roads and railways, campus areas of the Government buildings, educational institutions and industrial areas. Some areas were marked for development of offices, buildings, and institutions in future. In the absence of plan at that time, these areas were also planted in 1990s to maintain block plantations till the period of their development. The details of plantations by the department during the last four decades are given in Table-9.

A good number of labourers camp in the city area and they extract fuel wood from the dead branches or dead trees. Every year, a good number of trees dry and small dead trees of them were gradually used by the people for firewood. Such trees are not accounted and reflected in the figure of officially removed trees. Thus, official data of dead and fallen trees and also illegally cut trees do not present true picture.

Table-9 : Plantations during the last four decades in Gandhinagar Capital Project Area

| Year | Area of plantation (area in ha) | No of seedlings planted by the Forest Department | Average annual rate of plantation(seedlings/year) |
|--------------|------------------------------------|---|--|
| 1971-80 | 535.1 | 1,071,000 | 107,000 |
| 1981-90 | 328.1 | 382,500 | 38,250 |
| 1991-00 | 1063.9 | 1,665,900 | 166,600 |
| 2001-10 | 562.5 | 351,310 | 35,130 |
| Total | 2489.6 | 3,470,710 | 86,750 |

Table-10: Cutting of trees in Gandhinagar

| Year | Cutting of trees to facilitate development | | | Total |
|--------------|--|-----------------------|-----------------|----------------|
| | For development | Dead and fallen trees | Illegal cutting | |
| 2001-02 | 8,737 | 5,650 | 78 | 14,465 |
| 2002-03 | 3,972 | 17,879 | 374 | 22,215 |
| 2003-04 | 4,897 | 9,487 | 359 | 14,743 |
| 2004-05 | 2,875 | 4,153 | 139 | 7,167 |
| 2005-06 | 6,818 | 2,004 | 188 | 9,010 |
| 2006-07 | 12,682 | 4,601 | 74 | 17,357 |
| 2007-08 | 10,568 | 2,117 | 28 | 12,713 |
| 2008-09 | 9,583 | 2,328 | 58 | 11,769 |
| 2009-10 | 19,934 | 2,309 | 28 | 22,271 |
| 2010-11 | 2,914 | 5,039 | 140 | 8,093 |
| Total | 82,970 | 55,567 | 1,466 | 140,003 |

A total of 1.40 lakh trees were removed during the last ten years at an average annual rate of 14,000 trees.

Tree cover

The satellite imageries of different times were analyzed by the GIS Centre under Working Plan Wing of Gujarat Forest Department. Tree cover in Gandhinagar in different years is given in Table-2. It shows that the overall tree cover in Gandhinagar Capital Project area has increased from 1,993 ha to 3,256 ha between 1979 and 2005 but then declined marginally to 3,075 ha in 2011 due to the cutting of trees in certain areas to facilitate development.

Tree cover was very poor in the beginning of 1970s. Plantation drives have contributed to consistent improvement in greenery of the city and the cover improved to 1993.1 ha in 1979.

The dense tree cover estimated about 769.6 ha (about 13.5% of the total area-5,700 ha of the capital project) in 1979, increased consistently to 2126 ha in 1999 and then to 2427.0 ha. In 2005, reflecting a drastic increase due to afforestation drive. The area under open tree cover was 1223.5 ha in 1979. With progress of plantations, open areas first changed to open tree cover and then to dense tree cover over a period. Thus, with development of plantations, a large part of this has been transformed into dense tree cover. In all, tree cover in Gandhinagar Capital Project Area has increased consistently from 1993.1 ha in 1979 to 3256.2 ha in 2005. The developments of offices, institutions, and road widening have

Table-11: Status of tree cover in Gandhinagar Capital Project Area

| Sr. No. | Year | Tree Cover Category | | |
|---------|------|---------------------|-----------------|----------------|
| | | Dense tree cover | Open tree cover | Total |
| 1 | 1979 | 0769.6 (13.5%) | 1223.5 (21.5%) | 1993.1 (35.0%) |
| 2 | 1986 | 1146.3 (20.1%) | 1265.5 (22.2%) | 2411.8 (42.3%) |
| 3 | 1999 | 2126.0 (37.3%) | 0912.9 (16.0%) | 3038.9 (53.3%) |
| 4 | 2005 | 2427.0 (42.6%) | 0829.2 (14.6%) | 3256.2 (57.1%) |
| 5 | 2011 | 2073.7 (36.3%) | 1002.1 (17.6%) | 3074.7 (53.9%) |

Note : Area in ha., percentage of total geographical area is given in the brackets.

some impact on the tree cover. As a result, tree cover declined in 2008 due to cutting of trees to facilitate development and then again improved in 2011 to the level of 3,075 ha. Recently, tree cover improved in GEB complex and near Lekawada areas but declined in the area from Town Hall to Gandhi Convention centre and in the area of pond construction in Sector-1.

Tree population

The first systematic tree counting in all cities and towns of Gujarat, including Gandhinagar city was carried out in 2011. Some attempt was made in the past to count trees and plants, including new plantations but such records do not seem to be adequately compiled to present a picture. Systematic counting of trees having Girth at Breast Height (GBH) above 10 cm was done in all sectors and other areas in Gandhinagar, and a total of 8.67 lakh trees were counted. In addition to the trees, the number of established trees having height above 2.0 m but GBH below 10 cm was 4.80 lakh. The number of young plants or seedlings having height below 2.0 m was estimated to be 9.81 lakh.

A total of 226 species of trees were counted in Gandhinagar but few of them dominate in

tree cover. The main trees species and their population in Gandhinagar has been given in Table-12.

Neem is the main tree in Gandhinagar Capital Project Area and also in the district, constituting about one fifth of total trees in the city. First five trees-Neem, Garmalo or Amaltas, Gando-bavad, Israel bavad and Deshi bavad constitute about 55.1% of total tree population in the city.

(i) No of trees having girth at breast height (GBH) above 10 cm = 8,66,670 trees or 8.67 lakh trees

(ii) Very young trees and big sapling having height above 2.0 m but GBH below 10 cm = 4,79,690 trees

(iii) Seedlings or saplings or shrubby plants having height below 2.0 m = 9,80,980 plants

Tree having GBH above 10 cm is considered a tree for the purpose of analysis, and other categories are not included in the total tree population. In other words, the number of trees having girth above standard norm in Gandhinagar city was 8.67 lakh in 2011. Mango was the main tree species in the area before establishing Capital. A total of 6,599 trees of mango survive in the city area.

Table-12: Tree population of the main tree species

| Tree species | Botanical name | No of trees (in Lakh) | Tree species | Botanical name | No of trees (in Lakh) |
|-----------------|---------------------------------|-----------------------|--------------|----------------------------|-----------------------|
| 1. Neem | <i>Azadirachta indica</i> | 1.72 | 11. Nilgiri | <i>Eucalyptus sp.</i> | 0.17 |
| 2. Garmado | <i>Casia fistula</i> | 0.84 | 12. Amala | <i>Emblica officinalis</i> | 0.16 |
| 3. Gandobavad | <i>Prosopis chilensis</i> | 0.79 | 13. Pinkesia | <i>Cassia javanica</i> | 0.16 |
| 4. Israel bavad | <i>Acacia tortilis</i> | 0.78 | 14. Gorad | <i>A. senegal</i> | 0.11 |
| 5. Deshibavad | <i>A. nilotica</i> | 0.65 | 15. Ardusa | <i>Ailanthus excelsa</i> | 0.15 |
| 6. Kashid | <i>Casia siamia</i> | 0.39 | 16. Karnaj | <i>Pongamia pinnata</i> | 0.10 |
| 7. Bamboo | <i>Dendrocalamus strictus</i> | 0.32 | 17. Bordi | <i>Zyzyphus sp</i> | 0.10 |
| 8. Peltroform | <i>Peltroforum ferruginieum</i> | 0.27 | 18. Sirus | <i>Albizia lebbek</i> | 0.09 |
| 9. Kanji | <i>Holoptelia integrifolia</i> | 0.24 | 19. Sewan | <i>Gmeliana arborea</i> | 0.08 |
| 10. Asopalav | <i>Polyalthia longifolia</i> | 0.22 | 20. Others | | 1.23 |
| | | | Total | | 8.67 |

Tree density

Average tree density in Gandhinagar Municipal Area is 152 trees per hectare which is the highest in Gujarat and perhaps in the country also. The average tree density in Gandhinagar city area is almost ten times the average tree density in the non-forest areas of Gujarat.

In eight major cities-Municipal Corporations, the average tree density is about 28.6 trees/ha and Gandhinagar has density over six times of the tree density in the major cities in Gujarat. Out of eight Municipal Corporations in Gujarat, only three of them-Gandhinagar (152 trees/ha), Vadodara (45.8 trees/ha) and Bhavnagar (49.5trees/ha) have adequate tree cover above the average.

Gandhinagar - a green city

Relative assessment of tree cover or tree density compared to the greenest city in the world is not available and it is difficult to describe relative status of tree cover in Gandhinagar. Also, status of tree cover in the cities of India is not available in absence of tree counting there. The Forest Survey of India, Dehradun has provided the status of forest and tree cover in the two cities-

Delhi and Chandigadh, which are considered among the greenest cities in India. The status of forest and tree cover within boundary of the three cities-Delhi, Chandigadh and Gandhinagar is given in Table-13.

From the Tables below, it is clear that over half of the geographical area of Gandhinagar is under tree and forest cover whereas none of the other two green cities have even 15% of geographical area under tree and forest cover. In other words, tree density in Gandhinagar is much higher than the tree density in the other green cities-Delhi and Chandigadh. If correlation between tree density and tree cover, as observed in Gandhinagar, is applied to cities of Chandigadh and Delhi, the densities of trees in these cities should be about 42 trees /ha and 35 trees/ha, respectively. Logically, it appears that Gandhinagar is perhaps the greenest city in India but its status in the world is not known. In term of tree density, the capital of Gujarat may be a strong candidate for greenest city in the world. Being a non-megacity, the comparison of tree cover in Gandhinagar with other major city may not be logical.

Table-13: Tree cover in important cities in India

| Name of city | Total geographical area (sq. km.) | Forest and tree cover (sq. km.) | | Total tree and forest cover (sq. km) | Percent of geographical area |
|--------------|-----------------------------------|---------------------------------|------|--------------------------------------|------------------------------|
| | | Dense | open | | |
| Delhi | 1483 | 56 | 120 | 177 | 11.9% |
| Chandigadh | 114 | 11 | 6 | 17 | 14.9% |
| Gandhinagar | 57 | 21 | 10 | 31 | 53.9% |

Analysis of tree composition in Gandhinagar

| Distribution of trees in different girth classes | | | |
|--|-----------------|---------------|-----------------|
| Girth in cm | Number of trees | Girth in cm | Number of trees |
| 10-30 cm | 22,0150 | 121-150 cm | 27,410 |
| 31-60 cm | 306,310 | 151-200 cm | 14,370 |
| 61-90 cm | 212,890 | 201-250 cm | 2,870 |
| 91-120 cm | 81,360 | 250 and above | 1,310 |

Distribution of trees in different girth classes in 2011

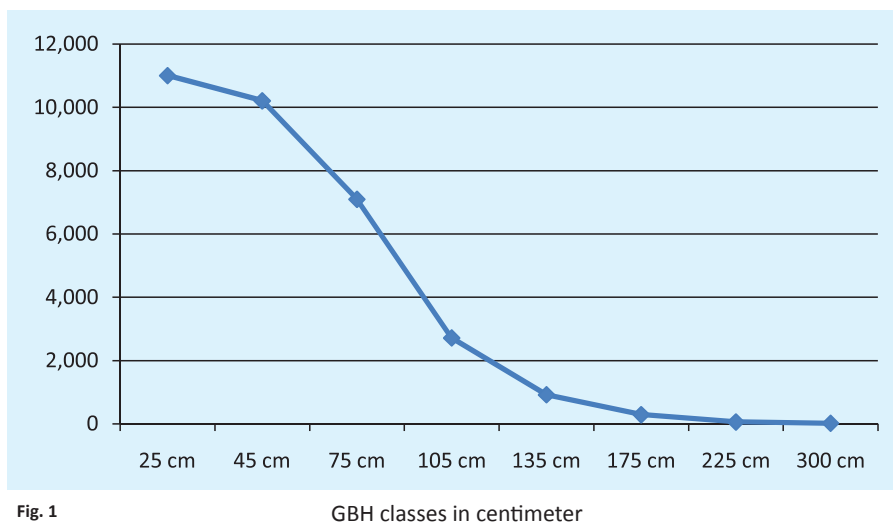


Fig. 1

GBH classes in centimeter

Scale of plantation was high during 1971-80 and also in 1991-2000 due to availability of blank spaces, but it slowed down during the last decade due to saturation of plantation and non-availability of open spaces. This is the main reason that number of trees in the lower girth classes or in low age is lower than the normal distribution. On the other hand, due to development of tree canopies of old plantations, a large area has come under dense tree cover. Low rate of plantation during the last decade due to non-availability of adequate land and also due to developmental activities have some impact on the number of young trees but not much on tree cover. Distribution of trees in different age classes reveals that the number of trees is high in middle and old age classes. Natural age of several species like *Kashid*, *Israeli bavad*, *Pincasia*, *Prosopis*, *Asopalav* etc. is low and they start dying naturally after three decades of their ages in dry soil in the semi-arid region. Also, numbers of long living trees like *khati-amli*, *rayan*, *mango*, *vad*, *pipad* etc. are very low. About 1.27 lakh (14.6%) trees have GBH above 90 cm and they are old. There are about 4,180 big trees having GBH above 2.0 m. Even trees with lower girth classes of several species like *kashid*, *Israeli bavad*, *Pincasia* etc. have reached to their maturity age and have started dying.

Carbon store and sequestration: Carbon store in the trees in Gandhinagar has been estimated about 1.79 lakh tones and annual sequestration rate may be about 68,00 Carbon tones per year.

Conclusion: The main reasons for loss of trees in Gandhinagar are: (i) the annual loss of trees due to natural factors like age, wind and other such factors may be about 2-3 % of total population of trees, (ii) allocation of the land for infrastructure development to meet needs of the Capital City, and (iii) increasing number of houses to accommodate growing population in the city. Thus, annual loss of trees may be in a range of 5.0 % to 7.5 % of total tree population in future. Thus, roughly about 7.5 % of total population of trees should be raised annually. If we assume 80 % survival percent after five years of plantation in Gandhinagar under high cost model of plantation, the scale of plantation should be **at least 80,000 tall** seedlings per year to maintain the present level of greenery in Gandhinagar. Also, the number of *Khati amli*, *Deshi mango* and *Rayan* may be improved as these long living trees are native to the area.

There are 39 villages in GUDA (Gandhinagar Urban Development Authority). These villages also have adequate tree cover but can be improved marginally.

13.2 Trees in Ahmedabad City

Ahmedabad is the largest city in Gujarat in term of human population and the area. The population density is very high within the city. On other hand, the tree cover is less in the old city, but some areas like cantonment have very good tree cover. If about 282 trees are accounted equivalent to one hectare, the tree cover in the city is estimated about 4.66 % of the geographical area, which is below the average tree cover in the urban areas in the state. The tree populations in different zones of the city are given in table-14.

About 117,100 trees were counted in patches of tree block which have area more than five hectare. About 57,880 trees were counted in

cantonment area in which share of large trees is relatively high.

The basic facts about Ahmedabad city are as follows.

| | |
|--------------------------------------|------------------------|
| Human population | 55.71 lakh |
| Area of city | 46,985 ha |
| Number of trees (above 10 cm GBH) | 618,050 lakh |
| Tree density | 13.1tees/ha |
| Tree cover | 6.66 % |
| Trees per 100 persons | 11.1 trees/100 persons |

Over 100 tree species were listed by the enumerators and the species having high number have given in Table-16.

Table-14: Zone-wise status of tree cover

| Zone/Area | Number of trees |
|-------------------------------|-----------------|
| 1. Central zone | 23,518 |
| 2. East zone | 75,497 |
| 3. West zone | 84,035 |
| 4. North zone | 60,677 |
| 5. South zone | 89,863 |
| 6. New west zone | 84,189 |
| 7. Parks and garden | 25,290 |
| 8. Cantonment and other areas | 174,979 |
| Total | 618,048 |

Table-15: Zone-wise status of tree density

| Zone | Area (in ha) | Tree density |
|---------------|---------------|--------------|
| Central zone | 1,650 | 18.5 |
| East zone | 7,852 | 10.9 |
| West zone | 5,653 | 10.8 |
| New west zone | 17,906 | 7.8 |
| North zone | 4,157 | 20.8 |
| South zone | 9,205 | 11.4 |
| Cantonment | 562 | 103.0 |
| Total | 46,985 | 13.1 |

Table-16: The population of important trees in order of population

| Tree species | Botanical name | No of trees (in Lakh) | Tree species | Botanical name | No of trees (in Lakh) |
|-------------------|--------------------------------|-----------------------|----------------|---------------------------------|-----------------------|
| 1. Neem | <i>Azadirachta indica</i> | 1.43 | 8. Peltroforum | <i>Peltroforum ferruginieum</i> | 0.19 |
| 2. Asopalav | <i>Polyalthia longifolia</i> | 0.71 | 9. Garmado | <i>Casia fistula</i> | 0.17 |
| 3. Kanji | <i>Holoptelia integrifolia</i> | 0.42 | 10. Su-bavad | <i>Leucaena leucocephala</i> | 0.15 |
| 4. Gulmohar | <i>Delonix regia</i> | 0.40 | 11. Pipad | <i>Ficus tsila</i> | 0.13 |
| 5. Deshi bavad | <i>A. nilotica</i> | 0.40 | 12. Champo | <i>Michalia champaca</i> | 0.08 |
| 6. Peepal/ Pipado | <i>Ficus religiosa</i> | 0.20 | 13. Others | | 1.72 |
| 7. Kasid | <i>Casia siamea</i> | 0.20 | Total | | 6.18 |

Distribution of trees in different girth classes

| Girth in cm | Number of trees | Girth in cm | Number of trees |
|-------------|-----------------|------------------|-----------------|
| 10-30 cm | 119,030 | 151-200 cm | 32,530 |
| 31-60 cm | 153,310 | 201-250 cm | 14,150 |
| 61-90 cm | 154,690 | 250 -300 cm | 6,720 |
| 91-120 cm | 78,870 | 300 cm and above | 2,310 |
| 121-150 cm | 56,730 | | |

Number of tree vrs GBH in Ahmedabad

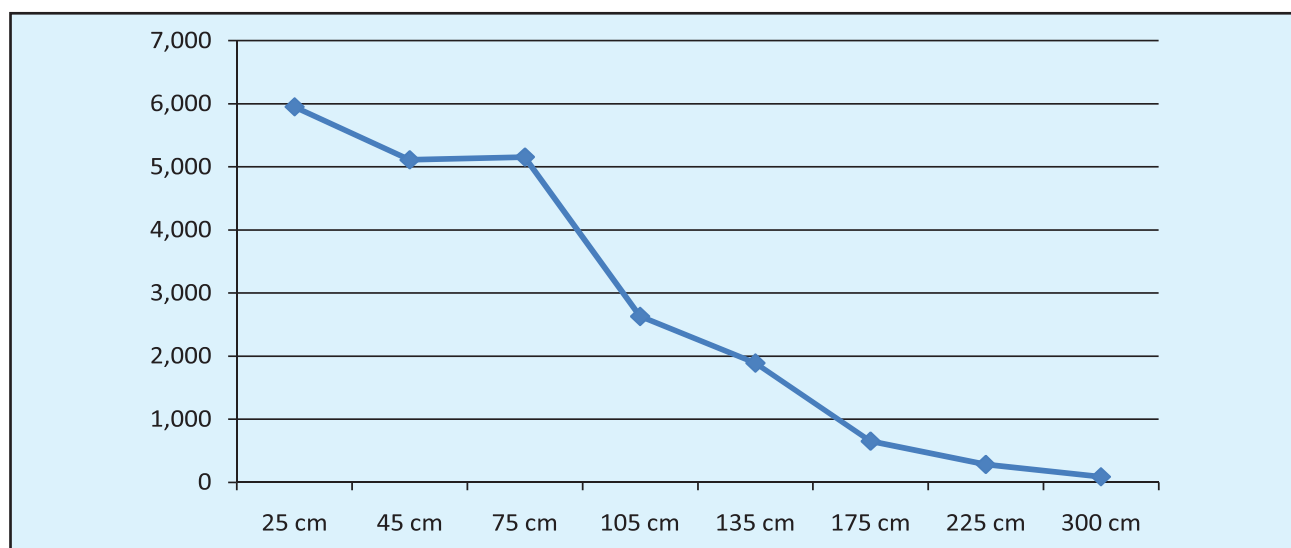


Fig. 2

A total of 6,415 trees have GBH between 250 and 300 cm and 2,311 trees have GBH above 300cm in Ahmedabad. This shows that the

number of big tree is relatively high. Majority of large tree belong to Neem, Peepal/Pipado, Kanji and Deshi bavad.

Neem is dominant tree as in other cities in the north Gujarat. A total of 2,437 Neem trees (1,717 between 250 to 300 cm and 720 trees above 300 cm) have girth at breast height above 250 cm and some of them are very old. Similarly, 1,240 trees of Pipado/Peepal have GBH above 250 cm. The number of Peepal tree (*Ficus religiosa*) is relatively high and they are also very old and large. Number of old trees having large size and dimension is also very high. Majority of trees near old textile mills, railway line, Kankaria zoo and cantonment area are old and large. In addition to above species, Badam, Sargavo, Borselli, Kasid are other major tree species in the city.

It is difficult to achieve a norm of green cover or green space as normally advocated for the urban areas in developed countries due to the lack of space. To achieve a minimum tree cover (15 % of geographical area) in the megacity, the total number of trees should be increased by three folds, which is possible to achieve by planting tall seedlings in the open space and compensating the gap by taking of tree plantation in the area of Ahmedabad Development Authority i.e peripheral villages.

The villages around Ahmedabad have poor tree cover. These 67 villages have about 7.95 lakh trees with density of 13.4 trees/ha and tree cover of 4.75 % of the geographical area. There are good numbers of bushes of *Prosopis chilensis* in these villages but they are not accounted for trees because they could not gain 10 cm girth at breast height due to their cutting at regular interval for fuel wood. The tree density in Gandhinagar district is four times the tree density in the area of AUDA. A part of AUDA is in Bhal area which is saline where growing trees is difficult. However, the authority should work to triple the tree density in the area of AUDA, as scope of improving greenery is less in the area of Amdabad Municipal Corporation (AMC).

Total tree population in the area of AMC and AUDA is 14.12 lakh. It may not possible to achieve a minimum norm of tree cover in the area of AMC and AUDA, but the administration should work to increase trees to the level of about 10% of geographical area. Thus, AMC and AUDA should work jointly to improve tree cover to the level of 30.1 lakh. The area around ponds/lakes should be planted and intensive horticulture and farm forestry may be promoted in the peripheral villages to reach near the target. The vacant institutional lands, compounds of schools, colleges, societies and other such areas may be used to raise trees.

Forest Department, AMC and AUDA joined hand to create a mass movement for greening Ahmedabad and planted a total of 8.55 lakh seedlings on 31st July, 2010. Of this, 4.01 lakh was planted in AMC and the rest of 4.54 seedlings were planted in the villages around Ahmedabad city (AUDA). The success of plantation in such a campaign is low, inviting criticism, but such campaign creates public awakening and mass participation in tree plantation and their subsequent care.

Development in and around Kankariya lake during the recent years as an important recreation site with greenery in the Zoo compound and around the lake is noteworthy. A large number of people visit area every day. Large and old trees provide resting and nesting sites for birds-a attraction for the visitors. Picturesque view of the lake and its surrounding area is due to the presence of trees around the lakes. There are about three dozen small and big lakes in the Municipal Corporation area and some of them may be developed in similar line by developing walk path and filling surrounding area with trees.

Carbon store in the trees in Ahmedabad city has been estimated about 1.27 lakh Carbon tone and annual sequestration rate may be over 4,640 Carbon tones.

Conclusion: It may be difficult to increase tree cover to 15 % of geographical area. The tree cover within the municipal corporation area may be improved to 10% by planting trees in gaps, institutional lands, streets and along Sabarmati River. About three dozen lakes may be developed by planting suitable trees like Neem, Khatai, Amli, *Ficus* sp. Development of tree groves or block

of tree plantations is necessary to avoid high temperature island in extreme summer. Thus, over seven lakh trees may be added in a period of ten years by planting about one and half lakh tall seedlings every year. Tree plantations should also be raised in peripheral villages to cover the gap.



Ahmedabad city near Kankaria Zoo



Concrete jungle with poor tree cover

13.3. Trees in Surat City

Surat is the second largest city in Gujarat in term of human population and the area. The human population density is very high within city. On other hand, the tree cover is poor. Surat has lowest tree density amongst the eight municipal corporations. Also, number of trees per hundred persons is also lowest. The industrial area of Surat near Hazira support good plantation. The basic facts about Surat city are as follows.

Unlike other *Mahanagar Palikas*, tree composition in Surat is different. Number of Neem trees is very low due to high rains. No specific species of tree has high population in Surat.

| | |
|--------------------------------------|------------|
| Human population | 44.62 lakh |
| Area of city | 39,550 ha |
| Number of trees (above 10 cm GBH) | 333,970 |

| | |
|----------------------|--------------------------------------|
| Tree density | 8.4 tees/ha |
| Tree cover | 1,184 ha (3.0% of geographical area) |
| Trees per 100 person | 7.5 trees/100 persons |

A total of 83 tree species have been listed during counting of trees and dominant species among them has been given in Table-17.

Surat has good rainfall but city and its peripheral villages have poor tree cover due to the nature of agricultural crops practiced. The tree cover can be improved to some extent in the Surat Municipal Corporation (SMC) area but may not be possible to increase to a desired level due to non-availability of the space. Thus, the gap may be filled up by taking up massive tree plantation and horticulture programmes in the area of Surat Urban Development Authority. SMC and SUDA may join hand to increase the tree population

Tabel-17. The main trees in Surat Mahanagar Palika

| No | Species | No of trees | No | Species | No of trees |
|----|--|-------------|----|----------------------------------|----------------|
| 1 | Asopalav- <i>Polyalthia longifolia</i> | 23,042 | 7 | Nilgiri- <i>Eucalyptus</i> sp | 10,031 |
| 2 | Saptarni- <i>Alstonia scholaris</i> | 11,973 | 8 | Chikoo- <i>Acrus sapota</i> | 9,423 |
| 3 | Gulmohar- <i>Delonix regia</i> | 11,406 | 9 | Badam- <i>Terminalia catappa</i> | 9,163 |
| 4 | Bakam Limdo- <i>Melia azedarach</i> | 11,110 | 10 | Kasid- <i>Casia siamea</i> | 8,661 |
| 5 | Gandobaval- <i>Prosopis chilensis</i> | 10,524 | 11 | Others | 218,470 |
| 6 | Gorasamli- <i>Pithecellobium dulce</i> | 10,187 | | Total | 333,990 |

Distribution of trees in different girth classes

| Girth in cm | Number of trees | Girth in cm | Number of trees |
|-------------|-----------------|---------------|-----------------|
| 10-30 cm | 97,728 | 121-150 cm | 3,846 |
| 31-60 cm | 15,0616 | 151-200 cm | 1,610 |
| 61-90 cm | 66,326 | 201-250 cm | 387 |
| 91-120 cm | 13,452 | 250 and above | 25 |

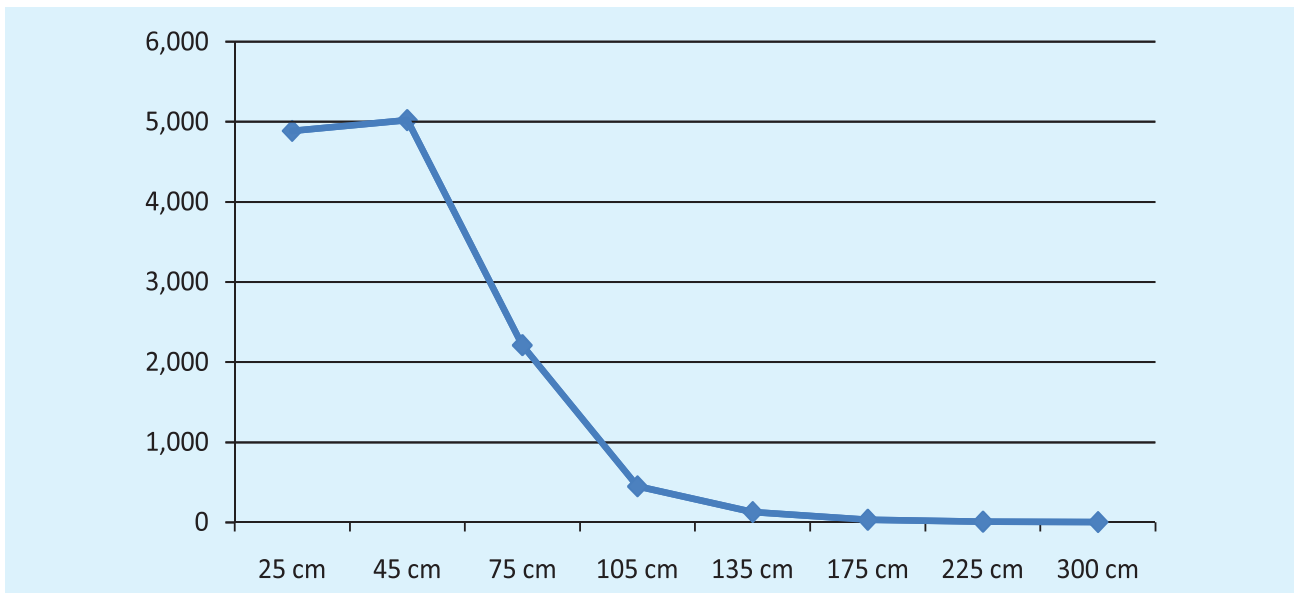


Fig. 3

from about 7.99 lakh to about 20.6 lakh. Thus, intensive tree plantation drive and horticulture development programmes should be taken in 94 villages under SUDA. The area around lakes/ponds in and around SMC should be planted to improve recreational value.

Forest Department successfully raised trees in the campus of National Institute of Technology, Surat over a period. In 2011, Forest Department planted more than 50,000 seedlings at about one and half dozen sites on the occasion of the Republic Day. Major part of this plantation was in SUDA. A block of plantation was also raised in the campus of Surat University. The results of these plantations are very good.

A large plantation was also done during the Van Mahotsav in 2010 as a part of green Surat Campaign. In this campaign, over 2.72 lakh seedlings were planted in and around the city and 1.80 seeds were planted in the intertidal zone at the mouth of Tapi River. The industrial areas in Hazira have been planted to raise environmental plantation. As a result, most of the industries have good tree cover, although these areas fall outside the SMC. The coastal forest near Hazira and mangroves at mouth of Tapi River add to ecological value of the city.

Within Surat city, there are two very old and large trees of Rukhada which were saved by the local people when authority planned to remove them to widen L. P. Sawani Road. Girth at Breat Height of these trees were 10.4 m and 9.3 m, respectively.

Conclusion: Tree cover is very poor in the city. It may not be possible to increase tree cover to 15% of geographical area but the canopy cover may be improved by 10 % of the city area by taking up intensive tree plantation. There is a need to increase tree population by about seven to eight lakh. Thus, about two lakh tall seedlings may be planted in available space, along Tapi River and institutional lands. Availability of the land for planting trees may be problem. If adequate space is not available, intensive agro-forestry and horticulture should be developed in peripheral villages.



Very poor tree cover in Surat city

13.4. Trees in Vadodara City

Vadodara, a cultural and educational city is the third largest megacity in Gujarat in the term of human population and area. It is also known as a city having a good number of Vad trees in the past. The tree cover in campus of Lakshmi Vilas Palace and the area from the Palace to the campus of MS University, Vadodara, Railway Staff College and along the Vishwamitri River is very good. In the term of greenery within city area, it is the second city after Gandhinagar. The dimension of trees is also very good,

The basic fact about Vadodara is as follow.

| | |
|--------------------------------------|--|
| Human population | 16.67 lakh |
| Area of city | 16,264 ha |
| Number of trees (above 10 cm GBH) | 747,200 |
| Tree density | 45.9 trees/ha |
| Tree cover | 2650 ha or 16.3% of geographical area |
| Trees per 100 person | 44.8 trees/100 persons |

Table-18: The main trees in Vadodara Mahanagar Palika

| Species | No of trees | Species | No of trees |
|--|-------------|--|----------------|
| 1. Limdo- <i>Azadirachta indica</i> | 45,440 | 7. Gulmohar- <i>Delonix regia</i> | 26,830 |
| 2. Peltiform - <i>Peltroforum ferruginieum</i> | 45,400 | 8. Pendula- <i>Polyalthia pendula</i> | 25,400 |
| 3. Saptarni- <i>Alstonia scholaris</i> | 37,450 | 9. Sharu- <i>Casuarina equisetifolia</i> | 22,310 |
| 4. Asopalav- <i>Polyalthia longifolia</i> | 34,850 | 10. Mango – <i>Mangifera indica</i> | 21,600 |
| 5. Kasid- <i>Casia siamea</i> | 30,010 | 11. Others | 430,940 |
| 6. Nilgiri- <i>Eucalyptus sp</i> | 26,970 | Total | 747,190 |

Distribution of trees in different girth classes

| Girth in cm | Number of trees | Girth in cm | Number of trees |
|-------------|-----------------|---------------|-----------------|
| 10-30 cm | 269,694 | 121-150 cm | 27,126 |
| 31-60 cm | 234,142 | 151-200 cm | 13,272 |
| 61-90 cm | 148,172 | 201-250 cm | 5,280 |
| 91-120 cm | 47,037 | 250 and above | 2,470 |

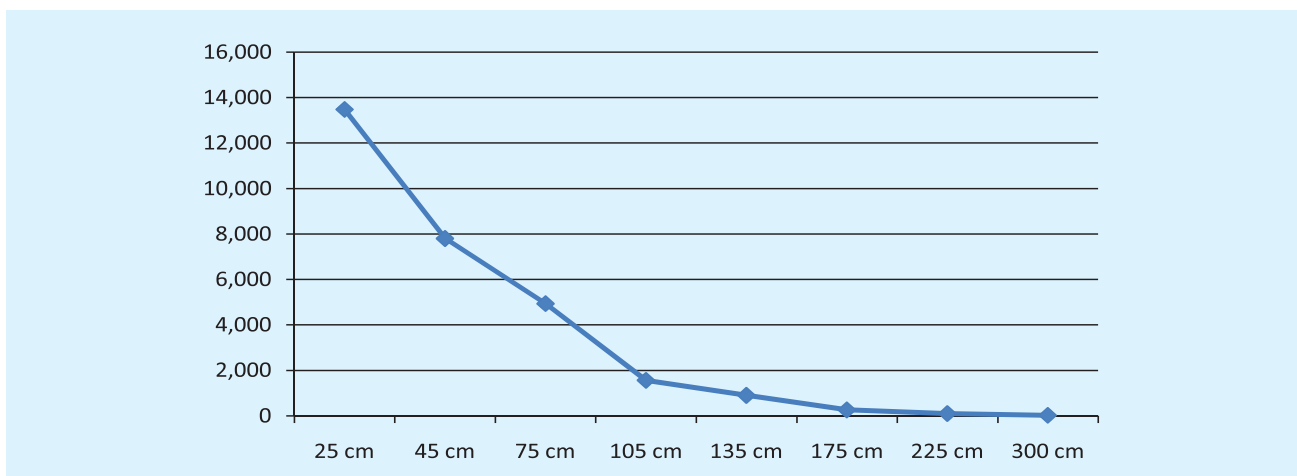


Fig. 4

A total of 151 species of trees were encountered in the city and ten most important of them have been given in Table-18.

Tree cover in Vadodara is very good and may be listed among the green city in India. Among four major cities having population over one million in Gujarat, the tree cover is highest in Vadodara.

Like Surat, the tree population is evenly distributed among different species. Palace compound, campus of Railway Staff College and open space along Vishwamitri River have good tree cover.

Number of trees having large dimension is very good. There are 5,280 trees which have girth between 200 and 250 cm and 2470 trees have GBH above 300 cm.

Over hundred crocodiles live in Vishwamitri River. Crowding of crocodiles in small Vishwamitri River within the Vadodara city area is an interesting. People do not harm these crocodile. Also, human injuries or death are very rare.

During greening Vadodara campaign in 2010, over 2.22 lakh seedlings/saplings were planted

in two days. Vadodara Municipal Corporation carries out tree plantation every year to improve greenery of the city.

There are several lakes and ponds in and around the city. The areas around these water bodies should be planted by suitable species like Vad, Pipal, Jamun, Neem, Khati-amli.

There is a large Banyan tree in the campus of Gujarat State Fertilizer Corporation Ltd. The canopy coverage of this tree is about 4,000 m. It is above 300 years old tree.

Carbon stock in the tree cover has been estimated about 1.55 lakh Carbon tones and annual sequestration rate by the growing stock is about 5,900 Carbon tones.

Conclusion: Tree cover is adequate within city area. Tree line may be maintained along Vishwamitri River. Vadodara is expanding in new area. The present norm of 15% tree cover should be maintained in the new society. There are several lakes/ponds in the city. Status of these water bodies and the banks of Vishwamitri river should be improved by planting suitable species.



Vadodara city area has adequate tree cover

13.5. Trees in Rajkot City

Tree cover in Rajkot, a largest city in Saurashtra, is below average. It is the fourth largest city in term of population and area, but has less tree cover. Neem is dominant species as a good number of old trees is found in the city. A total of 140 species of trees were encountered in the city and ten most important of them have been given in Table-19.

Neem is dominant species. Number of *Saptarni* tree has increased as this species has been planted in the city area during the

recent years. Large trees of Neem survive in the compound of old college and schools.

The facts about Rajkot are as follows.

| | |
|-----------------------------------|------------------------------------|
| Human population | 12.87 lakh |
| Area of city | 10,400 ha |
| Number of trees (above 10 cm GBH) | 137,500 |
| Tree density | 13.2 trees/ha |
| Tree cover | 488 ha (4.7% of geographical area) |
| Trees per 100 person | 10.7 trees |

Table-19: The main trees in Rajkot Maha Nagarpalika

| Species | No of trees | Species | No of trees |
|--|-------------|---|----------------|
| 1. Neem/Limdo - <i>Azadirachta indica</i> | 24,567 | 7. Gulmohar - <i>Delonix regia</i> | 6,338 |
| 2. Saptarni - <i>Alstonia scholaris</i> | 12,301 | 8. Kasid - <i>Casia siamea</i> | 4,631 |
| 3. Asopalav - <i>Polyalthia longifolia</i> | 8,418 | 9. Subaval - <i>Leucaena leucocephala</i> | 2,709 |
| 4. Pendula - <i>Polyalthia pendula</i> | 7,403 | 10. <i>Ficus tsila</i> | 2,595 |
| 5. Peltiform - <i>Peltroforum ferruginieum</i> | 6,976 | 11. others | 55,744 |
| 6. Karanj - <i>Pongamia pinnata</i> | 6,960 | Total | 137,522 |

Distribution of trees in different girth classes

| Girth in cm | Number of trees | Girth in cm | Number of trees |
|-------------|-----------------|---------------|-----------------|
| 10-30 cm | 38,870 | 121-150 cm | 3,780 |
| 31-60 cm | 56,140 | 151-200 cm | 1,980 |
| 61-90 cm | 26,140 | 201-250 cm | 770 |
| 91-120 cm | 9,110 | 250 and above | 750 |

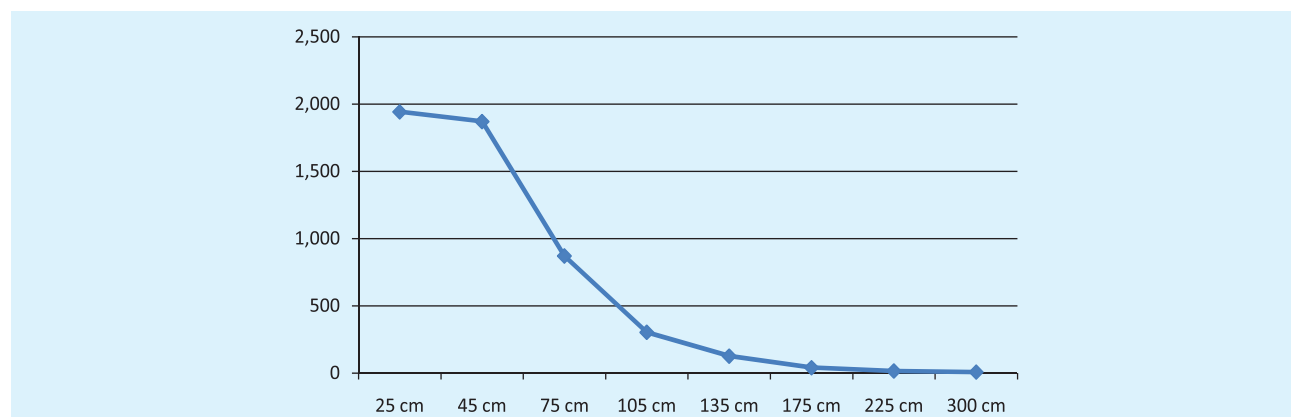


Fig. 5

There are about 750 large trees which have girth at breast height above 250 cm.

Tree density and tree cover is poor in Rajkot city. A good plantation has been done in the campus of Rajkot University and along a stream passing through the city.

Conclusion: Tree cover is very poor in Rajkot. In the absence of adequate trees and lakes/pond, there is a threat of development of high temperature islands during day time in extreme summer. Thus, available space may be covered by raising trees. Also, both sides of the stream passing through the city may be afforested. The target should be to double the tree population by planting tall seedlings in available space. To add additional about 1.5 lakh trees to achieve tree cover of 10% of geographical area of the city in ten years, over fifty thousand tall seedlings may be planted every year. Tree cover should also be improved in the peripheral villages.



Neem trees in a school compound



Plantation in campus of Rajkot University



13.6. Trees in Bhavnagar City

Bhavnagar is a coastal city with geographical area of 5,320 ha and human population of about 5.94 lakh. This city is second green city in Gujarat in term of tree density and tree cover. Victoria Park, a block of natural forest covering an area of 202 ha is within the limit of Bhavnagar Municipal Corporation Area. This is the main reason for high tree cover in Bhavnagar. Tree density is 1052 tree/ha in the Victoria Park and 51.5 trees/ha in the city area. Victoria Park support dense thorn forest having small trees.

The fact about Bhavnagar is as under.

| | |
|----------------------|--|
| Human population | 5.94 lakh |
| Area of city | 5,320 ha |
| Tree population | 476,000 |
| Tree density | 89.5 trees/ha |
| Tree cover | 1136 ha (934 ha in city and 202 ha in Victoria Park) |
| Trees per 100 person | 88.2 |

A total of 135 species of trees were encountered in the city and ten most important of them have been given in Table-20.

Table-20: Bhavnagar Mahanagar Palika (including Victoria Park)

| Species | No of trees | Species | No of trees |
|---|-------------|---|----------------|
| 1. Gorad- <i>Acacia senegal</i> | 180,260 | 7. Peltiform- <i>Peltroforum ferruginieum</i> | 10,470 |
| 2. Gandobaval- <i>Prosopis chilensis</i> | 55,040 | 8. Gulmohar- <i>Delonix regia</i> | 10,000 |
| 3. Limdo- <i>Azadirachta indica</i> | 30,260 | 9. Techoma- <i>Tecoma stans</i> | 7,740 |
| 4. Asopalav- <i>Polyalthia longifolia</i> | 18,830 | 10. Mango – <i>Mangifera indica</i> | 7,460 |
| 5. Subaval- <i>Leucaena leucocephala</i> | 12,080 | 11. Others | 132,790 |
| 6. Karanj- <i>Pongamia pinnata</i> | 11,110 | Total | 475,950 |

Table-21: The main trees in Bhavnagar (without Victoria Park)

| Species | Tree Population | Species | Tree Population |
|---|-----------------|-----------------------------------|-----------------|
| 1. <i>Prosopis chilensis</i> | 40,560 | 7. Gulmohar- <i>Delonix regia</i> | 9,970 |
| 2. Neem/Limado- <i>Azadirachta indica</i> | 29,320 | 8. Techoma- <i>Tecoma stans</i> | 7,720 |
| 3. Asopalav- <i>Polyalthia longifolia</i> | 18,740 | 9. Mango- <i>Mangifera indica</i> | 7,430 |
| 4. Karanj- <i>Pongamia pinnata</i> | 10,980 | 10. Badam- <i>T. catappa</i> | 6,520 |
| 5. Su-baval- <i>Leucaena leucocephala</i> | 10,510 | 11. Others | 111,200 |
| 6. <i>Peltroforum- Peltroforum ferruginieum</i> | 10,470 | Total | 263,430 |

Distribution of trees in different girth classes

| Girth in cm | Number of trees | Girth in cm | Number of trees |
|-------------|-----------------|---------------|-----------------|
| 10-30 cm | 146,380 | 121-150 cm | 12,730 |
| 31-60 cm | 180,350 | 151-200 cm | 11,040 |
| 61-90 cm | 100,960 | 201-250 cm | 2,590 |
| 91-120 cm | 20,740 | 250 and above | 1,170 |

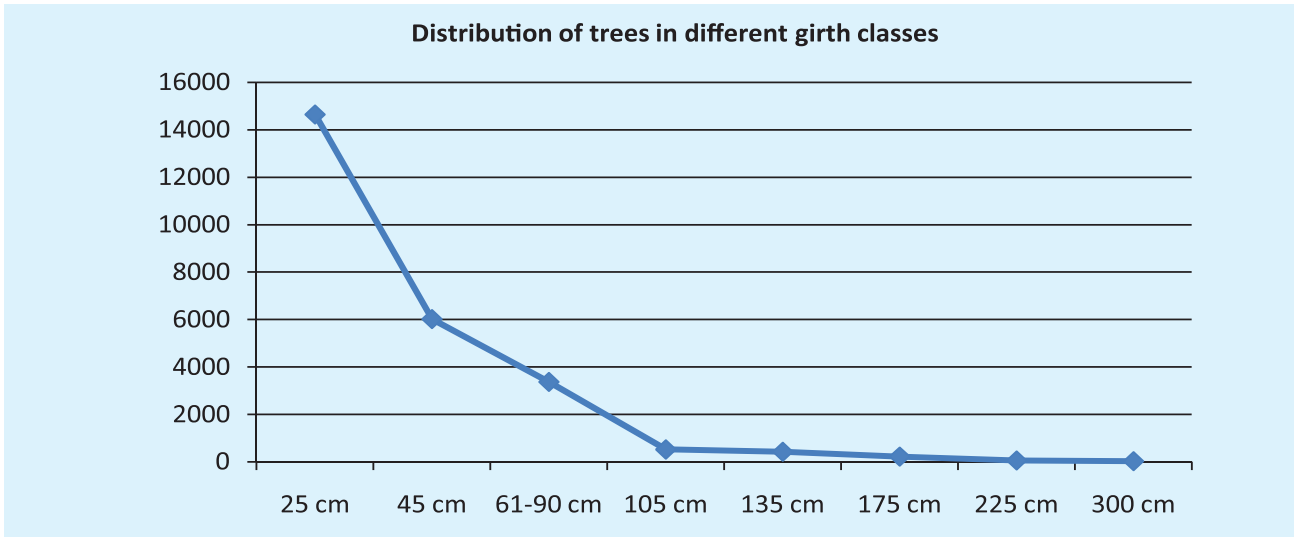


Fig. 6

The Victoria Park is a natural thorn forests but this patch of forest is within the limit of city. Gorad, a small but main tree of Saurashtra forest, has very high population in the forest. The tree composition in Bhavnagar changes with inclusion of Victoria Park. To know the Urban Trees, it is necessary to exclude trees of Victoria Park.

The distribution pattern of about 4.76 lakh trees in Bhavnagar has been given in above graph.

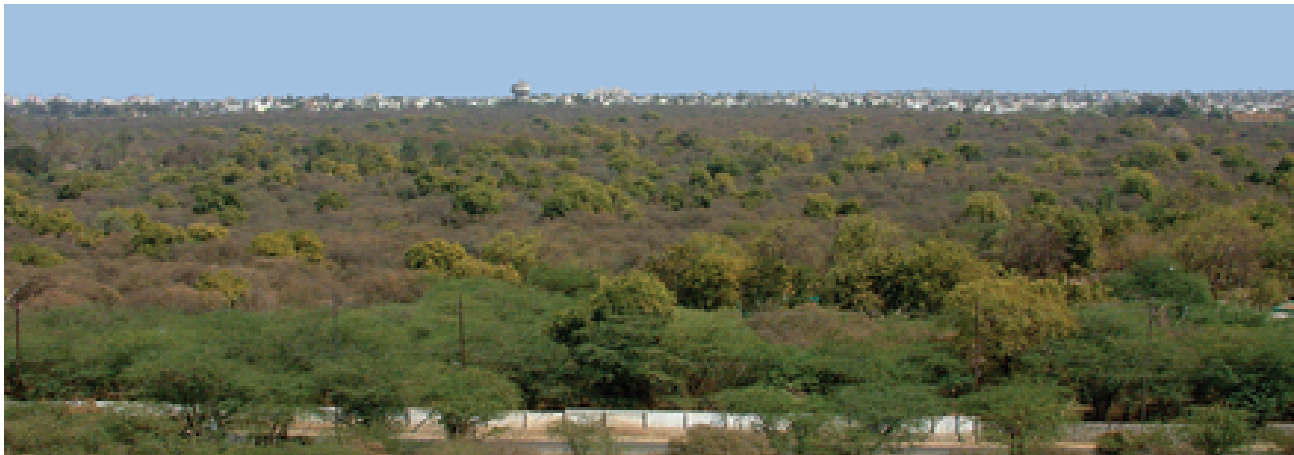
There are about 1,165 large trees having girth above 250 cm. Neem (491 trees), Vad (142 trees) Pipal (147 trees), Pipado (72 trees) and mango have good number of large trees.

Gorad is the main species in Victoria Park but its population is low in the city area. Black saline

soil in Bhavnagar is very suitable for *Prosopis chilensis*. As a result, this species naturally grow in the available space in the city.

A total of 160 species of trees have been counted in Bhavnagar urban area. Maximum diversity occurs in Victoria Park. This reserve forest is an important urban forest for the people, as it improves the urban life in the city. Victoria Park is also an important patch of thorn forest for the nesting of birds.

Conclusion; Tree cover is very good and it is above the norm. Victoria Park may be preserved as natural forest and may be managed as educational and recreation area. The attempt should be done to maintain greenery and also to improve to some extent by taking up plantations every year.



Victoria Park

13.7. Trees in Jamnagar

Jamnagar (Old name Nawanagar) is another coastal city. Area wise, it is smallest *Mahanagar Palika* in Gujarat with high density of human population and very low density of tree cover. The basic facts about the city are as follows. Neem and Bakam Neem are most important trees in the city. Also, Vad is present in good number along roads and in garden.

| | |
|----------------------|---------------------------------------|
| Human population | 5.29 lakh |
| Area of city | 3,434 ha |
| Tree population | 45,900 |
| Tree density | 12.9 trees/ha |
| Tree cover | 163 ha (4.7% of geographical area) |
| Trees per 100 person | 8.7 |

Only about 74 species of trees were encountered in the city and ten most important of them have been given in Table-22.

The coastal line of the *Mahanagar Palika* is saline and does not support trees. The inter-

tidal areas, beyond the boundary of the city, have forest cover of mangroves. Saline areas in periphery of the city is filled up by the bushes of *Prosopis chilensis*.

In Jamnagar, 315 trees are large having girth above 250 cm. Number of *Ficus* species-Vad is also good. These trees were raised before Independence by the then king of Jamnagar.

Distribution of about 45,880 trees in different girth classes has been presented in the above graph. Young trees or trees having low girth are relatively less. This indicates that there is a scope of planting suitable species in the available space within the municipal corporation area to improve green cover.

Conclusion: This city in Saurashtra has very poor tree cover which needs to be improved by three times. Some area of the city is saline. Thus a target to increase tree cover to the level of 10 % of the city area should be achieved by planting tall seedlings of suitable species.

Table-22: The main trees in Jamnagar Maha Nagarpalika

| No. | Species | No. of trees | No. | Species | No. of trees |
|-----|--|--------------|-----|---------------------------------------|---------------|
| 1 | Neem- <i>Azadirachta indica</i> | 6,838 | 7 | Nariyali- <i>Cocos nucifera</i> | 1,375 |
| 2 | Bakamlimdo- <i>Melia azedarach</i> | 2,851 | 8 | Subaval- <i>Leucaena leucocephala</i> | 1,295 |
| 3 | Gandobaval- <i>Prosopis chilensis</i> | 2,184 | 9 | Karanj- <i>Pongamia pinnata</i> | 1,249 |
| 4 | Asopalav- <i>Polyalthia longifolia</i> | 1,792 | 10 | Jamfal- <i>Psidium guajava</i> | 1,043 |
| 5 | Vad- <i>Ficus benghalensis</i> | 1,666 | 11 | Others | 24,206 |
| 6 | Deshibaval - <i>Acacia nilotica</i> | 1,378 | | Total | 45,877 |

Distribution of trees in different girth classes

| Girth in cm | Number of trees | Girth in cm | Number of trees |
|-------------|-----------------|---------------|-----------------|
| 10-30 cm | 7,420 | 121-150 cm | 2,950 |
| 31-60 cm | 13,670 | 151-200 cm | 2,130 |
| 61-90 cm | 12,870 | 201-250 cm | 1,130 |
| 91-120 cm | 4,860 | 250 and above | 320 |

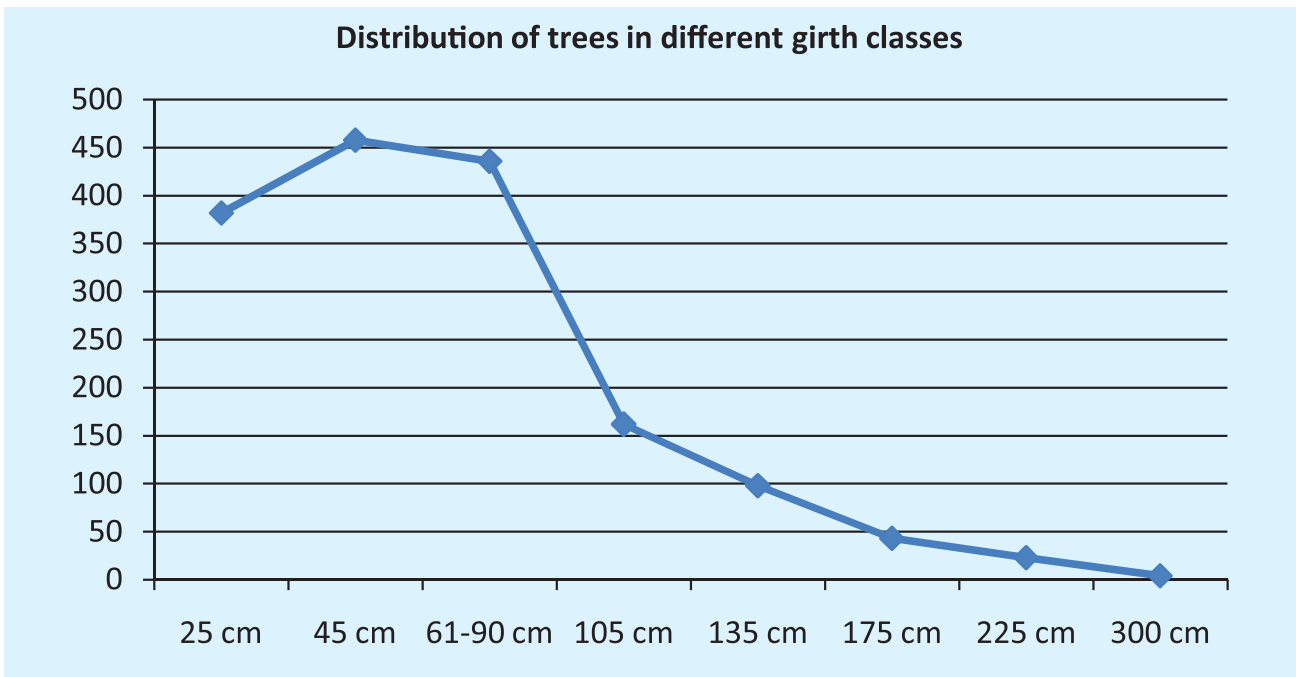


Fig. 7



Jamnagar city has a beautiful lake but very poor tree cover

13.8. Trees in Junagadh City

Junagadh is the smallest *Mahanagar Palika*, after Gandhinagar, in the term of human population in Gujarat State. The tree cover within city area is moderate but the surrounding areas have dense forest of Girnar. Areas in Agriculture University and Sakkarbuag have very good tree cover but the number is low in the main city. A large part of Sakkarbuag Zoo, having dense tree canopy is out of the boundary of municipal corporation, although it is most important recreational and educational area for the people of the city. Due to the presence of Agricultural University in the city, fruit bearing species like Nariyali, Chikoo, Guvava-Jamfal, and *Sitafal* are dominant among the trees in the city. Although *Pendula*, *Nariyali* and *Sitafal* have high populations, the presence of Neem and Mango trees appears high due to their large canopy dimensions.

The basic facts of Junagadh are as follows.

| | |
|----------------------|---|
| Human population | 3.20 lakh |
| Area of city | 5,670 ha |
| Tree population | 76,700 |
| Tree density | 13.5 trees/ha |
| Tree cover | About 271 ha (4.8% of geographical area) |
| Trees per 100 person | 23.4 |

A total of 127 species of trees were encountered in the city and ten most important of them have been given in Table-23.

The dense forest adjoining Junagadh (at boundary of the city) supports Teak, Khakharo, Deshi babool and other such forestry species. Asiatic lion frequently visit the area at boundary of the city. Girnar *talahati*, an important human habitation and a part of Junagadh Municipal Corporation is within Girnar forest. Catchment area of Girnar is a main source of water supply. There are several religious sites within Girnar mountain which are connected with Junagadh city. In fact, Sakkarbuag Zoo, area around Girnar talahati, forest nurseries and biodiversity cum educational site and several sites within Girnar are important recreational sites. These areas practically improve green space for the people, although they are not part of municipal corporation area.

- (i) In Junagadh, number of old trees is high. A large number of trees planted by the Nawab of Junagadh survives in the city. Over hundred year old trees of Mahoghany and Borselli survive in the city. Total of 149 trees in the city have girth above 300 cm and 546 trees have girth in the girth class 250-300 cm. Number of trees in lower girth class is relatively low.
- (ii) Number of *Nariyali* is also very high as a total of 6,550 *Nariyali* trees were counted within the city boundaries.

Table-23: The main trees in Junagadh Mahanagar Palika

| No | Species | No of trees | No | Species | No of trees |
|----|--------------------------------------|-------------|----|--------------------------------|--------------|
| 1 | <i>Pendula-Polyalthia longifolia</i> | 10,290 | 7 | Nilgiri- <i>Eucalyptus</i> sp | 2,380 |
| 2 | <i>Nariyali-Cocos nucifera</i> | 6,550 | 8 | Pipal- <i>Ficus tsila</i> | 2,350 |
| 3 | <i>Limdo-Azadirachta indica</i> | 5,320 | 9 | Jamfal- <i>Psidium guajava</i> | 1,980 |
| 4 | <i>Sitafal-Annona squamosa</i> | 4,060 | 10 | Ravana | 1,850 |
| 5 | Mango - <i>Mangifera indica</i> | 4,010 | 11 | Others | 35,230 |
| 6 | <i>Chikoo-Acrus sapota</i> | 2,680 | | Total | 76690 |

Distribution of trees in different girth classes

| Girth in cm | Number of trees | Girth in cm | Number of trees |
|-------------|-----------------|---------------|-----------------|
| 10-30 cm | 18,350 | 151-200 cm | 3640 |
| 31-60 cm | 26,870 | 201-250 cm | 900 |
| 61-90 cm | 15,060 | 250 and 300 | 550 |
| 91-120 cm | 6,890 | 300 and above | 150 |
| 121-150 cm | 4,280 | | |

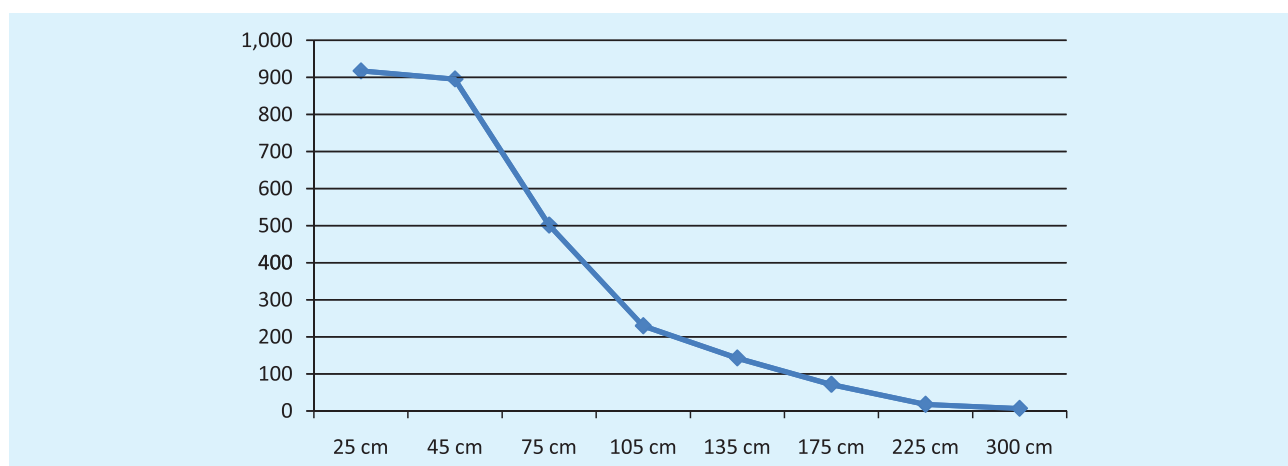


Fig. 8

(iii) Major part of the Sakkarbuag Zoo is reserve forest and it is located outside the boundary of Mahanagar Palika. Thus, the dense patch of tree cover in the area adjoining boundary of the city was not covered in the tree counting.

(iv) Junagadh Mahanagar Palika is surrounded by dense forest of Girnar. Within the city boundary, the tree cover is not high but a large

area of dense forests bordering the boundary of Municipal Corporation practically enhances tree cover. Thus, forest and tree cover is adequate in and around Junagadh. A part of Girnar mountain, with dense forest, practically is an integral part of the city.

(v) Number of old trees is relatively high in the city area compared to other cities.



The tree cover of Junagadh city area is moderate but the surrounding areas have dense forest of Girnar

14. Recommendations

Like the developed countries, the majority of Asian, particularly Gujarat people will live in their cities. Although still one of the less urbanised continents, the share of the Asian population living in urban areas has grown from 32% in 1990 to 42% in 2010. The United Nations forecasts that half of Asians will be in cities by 2026, but Gujarat may reach to this stage earlier, perhaps in a decade²². Amongst the major 22 cities in a study to describe the Asian Green City Index (four from India), only Delhi has environmental status above average and the rest of the major cities-Calcutta, Mumbai and Bangalore have average or below average environment status²⁵. There is need to address environment issues, including green cover in the urban areas of Gujarat for better life of its citizen. The environment status of a city is dependent on several parameters such as waste disposal, clean air, and green space.

Cities in USA and Europe have more green space than cities in Asia. As mentioned earlier, some green cities in Asia have 20 to 30 percent of their geographical areas under green cover, or 40 square meter (m²) of urban green open space per capita, based on population pressure. Green space in this case includes tree and forest cover, garden and parks and such other open space. In majority of the cases, tree and forest cover is more than half of the green space. Three municipal corporations and about two dozen municipalities already have tree cover above this norm. Thus, planning for improving tree and forest cover to the level of 15 % of the geographical area of the rest of municipal corporations and municipalities should be the target of the authorities.

Certain areas such as Ahmedabad and its satellite areas in Bopal, Sanand, Vogodara and neighbouring Bhal areas are being filled by concrete structures at the cost of wetlands, natural vegetation and agricultural lands. With

expansion of concrete jungle and decline in tree cover, threat of development of temporary hot temperature islands, beyond tolerance of human beings, in the absence of adequate tree cover or other such vegetation during the extreme summer in a large urban landscape is not ruled out. To avoid such possible scenario, maintaining certain percent of tree cover in the semi-arid environment having intense sunlight and low rains is necessary. Thus, to avoid such a possible scenario and also to improve environmental status of a city, following actions have been recommended for improving green cover.

- (i) Planning of urban forestry should be linked with planning in the energy, water supply, urban infrastructure, waste disposal, reclamation sites and construction of houses and buildings. Tree cover should be considered as an infrastructure for sustaining human population with quality life.
- (ii) Existing patches of natural and man-made urban forest like Victoria Park and Indroda Park should be preserved and enriched, and they should be managed as important recreational and educational centres.
- (iii) Cultural forest like *Punit Van* in Gandhinagar or *Mangalya* at Amabji should be raised in and around the city. The available wasteland or common land should be converted into woodlands dotted in an urban landscape. In other words, every city should have dotted patches of tree groves or forest in the landscape of concrete jungle. Large blocks of lands (above 5 ha) should be identified in periphery of the urban areas or in peripheral villages for developing urban or recreational forest or *Sanskrtitic Van* or tree garden to provide recreational space to the people and also for improving quality of urban life.

- (iv) Open space in the city-institutional areas, society and parks and along streets should be planted by suitable species. Small to medium sized tree species should be planted along roads and streets.
- (v) River bank plantation should be raised along river or stream passing through the urban area. The river bank should be transformed into recreation site by improving greenery. Thick green belt should be raised along the canal, aiming to create patches of recreational area using canal water.
- (vi) Expansion of city or urbanization or establishment of new building society should be permitted after approval of tree plantation plan in adequate area, say about at least 15% of the development areas.
- (vii) Lakes and ponds in and around the urban areas should be preserved and developed. Trees like *Ficus* sp. Khati-amli, Mango, Jamun, Neem and Deshi-babool should be planted to attract urban people and also birds in a line of Kankaria lake.
- (viii) Reclamation sites should be covered by raising tree plantation blocks.
- (ix) Terrace gardening should be permitted to improve green space.
- (x) Tall seedlings of suitable species should be planted in large pits with adequate care. Frequent watering and application of fertilizer should be done in such a manner that plants gain tree shape in two years. Nagar Nandan Van Yojana may be renewed in a revised form to increase tree cover.
- (xi) Dense tree cover in the peripheral villages or area under Urban Development Authorities should serve as green shield or tree shelter belt around the concrete jungle to moderate the environment of the city.
- (xii) Attempt should be made to cover every building by tree line around it.
- (xiii) Forest Department and Urban Development Departments and authorities should deliberate this issue to evolve appropriate strategies to improve tree cover in the cities.



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Annexure - I: Tree census in Urban Area (159 Nagarpalikas)

| Sr. No. | District | Nagarpalika | Area of Nagarpalika (in Ha) | No of Trees | Tree/Ha | Tree cover (in ha) | Tree cover % of geographical area |
|--------------|----------------|---------------|-----------------------------|--------------|-------------|--------------------|-----------------------------------|
| 1 | Panchmahal | Godhra | 2000 | 30338 | 15.17 | 107.6 | 5.4 |
| | | Shehra | 1839 | 5720 | 3.11 | 20.3 | 1.1 |
| | | Lunavada | 1277 | 12622 | 9.88 | 44.8 | 3.5 |
| | | Kalol | 764 | 14466 | 18.93 | 51.3 | 6.7 |
| | | Halol | 2120 | 13178 | 6.22 | 46.7 | 2.2 |
| | | Santarampur | 1600 | 14326 | 8.95 | 50.8 | 3.2 |
| | | Total | 9600 | 90650 | 9.44 | 321.5 | 3.3 |
| 2 | Surendranagar | Surendranagar | 3687 | 11903 | 3.23 | 42.2 | 1.1 |
| | | Vadhavan | 2001 | 5768 | 2.88 | 20.5 | 1.0 |
| | | Patdi | 527 | 2810 | 5.33 | 10.0 | 1.9 |
| | | Halvad | 1800 | 8457 | 4.70 | 30.0 | 1.7 |
| | | Chotila | 400 | 6043 | 15.11 | 21.4 | 5.4 |
| | | Thangadh | 1150 | 12625 | 10.98 | 44.8 | 3.9 |
| | | Dhrangadhra | 1430 | 4800 | 3.36 | 17.0 | 1.2 |
| | | Limdi | 1680 | 8044 | 4.79 | 28.5 | 1.7 |
| | | Total | 12675 | 60450 | 4.77 | 214.4 | 1.7 |
| 3 | Kheda | Nadiad | 2816 | 58769 | 20.87 | 208.4 | 7.4 |
| | | Kanjari | 803 | 64100 | 79.83 | 227.3 | 28.3 |
| | | Chaklasi | 2272 | 55329 | 24.35 | 196.2 | 8.6 |
| | | Kapadvanj | 849 | 7123 | 8.39 | 25.3 | 3.0 |
| | | Kheda | 291 | 1506 | 5.18 | 5.3 | 1.8 |
| | | Mahudha | 138.20 | 1435 | 10.38 | 5.1 | 3.7 |
| | | Thasara | 23.40 | 1028 | 43.93 | 3.6 | 15.6 |
| | | Dakor | 95.07 | 5200 | 54.70 | 18.4 | 19.4 |
| | | Balashinor | 343.73 | 12410 | 36.10 | 44.0 | 12.8 |
| | | Mahemdavad | 279 | 6886 | 24.68 | 24.4 | 8.8 |
| | | Kathlal | 343.32 | 16821 | 49.00 | 59.6 | 17.4 |
| Total | 8253.72 | 230607 | 27.94 | 817.8 | 9.9 | | |
| 4 | Anand | Umreth | 408 | 32721 | 80.20 | 116.0 | 28.4 |
| | | Petlad | 919 | 43230 | 47.04 | 153.3 | 16.7 |
| | | Sojitra | 620 | 26829 | 43.27 | 95.1 | 15.3 |
| | | Borsad | 2528 | 36989 | 14.63 | 131.2 | 5.2 |
| | | Anklav | 2184 | 118435 | 54.23 | 420.0 | 19.2 |

| Sr. No. | District | Nagarpalika | Area of Nagar-palika (in Ha) | No of Trees | Tree/Ha | Tree cover (in ha) | Tree cover % of geographical area |
|---------|-----------|--------------------|------------------------------|---------------|--------------|--------------------|-----------------------------------|
| | | Khambhat | 692.4 | 28769 | 41.55 | 102.0 | 14.7 |
| | | Anand | 2170 | 97000 | 44.70 | 344.0 | 15.9 |
| | | Karamsad | 1691 | 65949 | 39.00 | 233.9 | 13.8 |
| | | Vallabh Vidyanagar | 230 | 3940 | 17.13 | 14.0 | 6.1 |
| | | Boriyavi | 542 | 24930 | 46.00 | 88.4 | 16.3 |
| | | Odd | 4264 | 174824 | 41.00 | 619.9 | 14.5 |
| | | Total | 16248.4 | 653616 | 40.23 | 2317.8 | 14.3 |
| 5 | Ahmedabad | Sanand | 4041 | 10176 | 2.52 | 36.1 | 0.9 |
| | | Bareja | 2036 | 47907 | 23.53 | 169.9 | 8.3 |
| | | Bavala | 2312 | 6734 | 2.91 | 23.9 | 1.0 |
| | | Barvala | 1200 | 5449 | 4.54 | 19.3 | 1.6 |
| | | Dhandhuka | 6694 | 3134 | 0.47 | 11.1 | 0.2 |
| | | Viramgam | 878 | 8695 | 9.90 | 30.8 | 3.5 |
| | | Dholka | 1527 | 18294 | 11.98 | 64.9 | 4.2 |
| | | Total | 18688 | 100389 | 5.37 | 356.0 | 1.9 |
| 6 | Dahod | Zalod | 905 | 8538 | 9.43 | 30.3 | 3.3 |
| | | Bariya | 949 | 12010 | 12.66 | 42.6 | 4.5 |
| | | Dahod | 688.21 | 24113 | 35.04 | 85.5 | 12.4 |
| | | Total | 2542.21 | 44661 | 17.57 | 158.4 | 6.2 |
| 7 | Junagadh | Vanthali | 1950 | 22825 | 11.71 | 80.9 | 4.2 |
| | | Manavadar | 615 | 5538 | 9.00 | 19.6 | 3.2 |
| | | Bantava | 300 | 2481 | 8.27 | 8.8 | 2.9 |
| | | Mangrol | 1137.5 | 42613 | 37.46 | 151.1 | 13.3 |
| | | Keshod | 1600 | 19743 | 12.34 | 70.0 | 4.4 |
| | | Chorvad | 1300 | 55769 | 42.90 | 197.8 | 15.2 |
| | | Talala | 963 | 20466 | 21.25 | 72.6 | 7.5 |
| | | Veraval | 958 | 22388 | 23.37 | 79.4 | 8.3 |
| | | Sutrapada | 715 | 16895 | 23.63 | 59.9 | 8.4 |
| | | Una | 3740 | 51545 | 13.78 | 182.8 | 4.9 |
| | | Kodinar | 1600 | 20701 | 12.94 | 73.4 | 4.6 |
| | | Vishavadar | 418 | 6198 | 14.83 | 22.0 | 5.3 |
| | | Total | 15296.5 | 287162 | 18.77 | 1018.3 | 6.7 |
| 8 | Bhavnagar | Talaja | 1438 | 51130 | 35.56 | 181.3 | 12.6 |
| | | Mahuva | 3323 | 81210 | 24.44 | 288.0 | 8.7 |

| Sr. No. | District | Nagarpalika | Area of Nagar-palika (in Ha) | No of Trees | Tree/Ha | Tree cover (in ha) | Tree cover % of geographical area |
|---------|----------|--------------|------------------------------|---------------|--------------|--------------------|-----------------------------------|
| | | Palitana | 1205 | 29882 | 24.80 | 106.0 | 8.8 |
| | | Gariyadhar | 633 | 10408 | 16.44 | 36.9 | 5.8 |
| | | Shihor | 472 | 22850 | 48.41 | 81.0 | 17.2 |
| | | Gadhda | 650 | 17024 | 26.19 | 60.4 | 9.3 |
| | | Valbhipur | 237 | 12890 | 54.39 | 45.7 | 19.3 |
| | | Botad | 1036 | 27500 | 26.54 | 97.5 | 9.4 |
| | | Total | 8994 | 252894 | 28.12 | 896.8 | 10.0 |
| 9 | Rajkot | Dhoraji | 946 | 14201 | 15.01 | 50.4 | 5.3 |
| | | Vankaner | 450 | 4984 | 11.08 | 17.7 | 3.9 |
| | | Jetpur | 3600 | 26571 | 7.38 | 94.2 | 2.6 |
| | | Gondal | 1500 | 63684 | 42.46 | 225.8 | 15.1 |
| | | Morbi | 1500 | 31023 | 20.68 | 110.0 | 7.3 |
| | | Maliya | 2100 | 2369 | 1.13 | 8.4 | 0.4 |
| | | Upleta | 550 | 17698 | 32.18 | 62.8 | 11.4 |
| | | Jasdan | 1600 | 14583 | 9.11 | 51.7 | 3.2 |
| | | Bhayavadar | 212 | 3007 | 14.18 | 10.7 | 5.0 |
| | | Total | 12458 | 178120 | 14.30 | 631.6 | 5.1 |
| 10 | Amreli | Amreli | 1342 | 20782 | 15.49 | 73.7 | 5.5 |
| | | Savarkundala | 800 | 20762 | 25.95 | 73.6 | 9.2 |
| | | Bagsara | 875 | 11178 | 12.77 | 39.6 | 4.5 |
| | | Jafarabad | 415 | 10825 | 26.08 | 38.4 | 9.2 |
| | | Rajula | 439 | 13301 | 30.30 | 47.2 | 10.7 |
| | | Chalala | 500 | 8100 | 16.20 | 28.7 | 5.7 |
| | | Lathi | 600 | 5928 | 9.88 | 21.0 | 3.5 |
| | | Babra | 600 | 3258 | 5.43 | 11.6 | 1.9 |
| | | Damnagar | 1200 | 6304 | 5.25 | 22.4 | 1.9 |
| | | Total | 6771 | 100438 | 14.83 | 356.2 | 5.3 |
| 11 | Jamnagar | Kalavad | 320 | 5045 | 15.77 | 17.9 | 5.6 |
| | | Dhrol | 800 | 6952 | 8.69 | 24.7 | 3.1 |
| | | Jamjodhpur | 365 | 4585 | 12.56 | 16.3 | 4.5 |
| | | Salaya | 274 | 2378 | 8.68 | 8.4 | 3.1 |
| | | Khambhaliya | 624 | 3513 | 5.63 | 12.5 | 2.0 |
| | | Sikka | 585 | 8210 | 14.03 | 29.1 | 5.0 |
| | | Bhanvad | 934 | 1908 | 2.04 | 6.8 | 0.7 |

| Sr. No. | District | Nagarpalika | Area of Nagar-palika (in Ha) | No of Trees | Tree/Ha | Tree cover (in ha) | Tree cover % of geographical area |
|---------|-------------|------------------|------------------------------|---------------|-------------|--------------------|-----------------------------------|
| | | Dwarka | 421 | 7737 | 18.38 | 27.4 | 6.5 |
| | | Okha | 439 | 7076 | 16.12 | 25.1 | 5.7 |
| | | Raval(Kalyanpur) | 700 | 2184 | 3.12 | 7.7 | 1.1 |
| | | Total | 5462 | 49588 | 9.08 | 175.8 | 3.2 |
| 12 | Kachchh | Mandavi | 1400 | 6688 | 4.78 | 23.7 | 1.7 |
| | | Bhuj | 5600 | 22628 | 4.04 | 80.2 | 1.4 |
| | | Anjar | 1781 | 9224 | 5.18 | 32.7 | 1.8 |
| | | Gandhidham | 2958 | 24906 | 8.42 | 88.3 | 3.0 |
| | | Bhachau | 1409 | 3404 | 2.42 | 12.1 | 0.9 |
| | | Rapar | 3229.35 | 2348 | 0.73 | 8.3 | 0.3 |
| | | Total | 16377.35 | 69198 | 4.23 | 245.4 | 1.5 |
| 13 | Patan | Siddhpur | 800 | 7690 | 9.61 | 27.3 | 3.4 |
| | | Patan | 1332 | 8877 | 6.66 | 31.5 | 2.4 |
| | | Harij | 563 | 1562 | 2.77 | 5.5 | 1.0 |
| | | Radhanpur | 3216 | 5310 | 1.65 | 18.8 | 0.6 |
| | | Chanashma | 265 | 13652 | 51.52 | 48.4 | 18.3 |
| | | Total | 6176 | 37091 | 6.01 | 131.5 | 2.1 |
| 14 | Banaskantha | Palanpur | 2348 | 22625 | 9.64 | 80.2 | 3.4 |
| | | Disa | 2016 | 9723 | 4.82 | 34.5 | 1.7 |
| | | Dhanera | 900 | 4169 | 4.63 | 14.8 | 1.6 |
| | | Tharad | 1500 | 4357 | 2.90 | 15.5 | 1.0 |
| | | Bhanbhar | 192 | 1123 | 5.85 | 4.0 | 2.1 |
| | | Thara | 1629 | 2972 | 1.82 | 10.5 | 0.6 |
| | | Total | 8585 | 44969 | 5.24 | 159.5 | 1.9 |
| 15 | Mahesana | Mahesana | 3200 | 42366 | 13.24 | 150.2 | 4.7 |
| | | Kadi | 1500 | 9823 | 6.55 | 34.8 | 2.3 |
| | | Unjha | 3515 | 9635 | 2.74 | 34.2 | 1.0 |
| | | Visnagar | 790 | 11221 | 14.20 | 39.8 | 5.0 |
| | | Vadnagar | 4287 | 24610 | 5.74 | 87.3 | 2.0 |
| | | Kheralu | 350 | 6431 | 18.37 | 22.8 | 6.5 |
| | | Vijapur | 348 | 5485 | 15.76 | 19.5 | 5.6 |
| | | Total | 13990 | 109571 | 7.83 | 388.5 | 2.8 |
| 16 | Sabarkantha | Himmatnagar | 882 | 8153 | 9.24 | 28.9 | 3.3 |
| | | Modasa | 1320 | 8519 | 6.45 | 30.2 | 2.3 |

| Sr. No. | District | Nagarpalika | Area of Nagar-palika (in Ha) | No of Trees | Tree/Ha | Tree cover (in ha) | Tree cover % of geographical area |
|---------|----------|-----------------|------------------------------|---------------|--------------|--------------------|-----------------------------------|
| | | Idar | 1569 | 9349 | 5.96 | 33.2 | 2.1 |
| | | Khedbrahma | 273 | 5773 | 21.15 | 20.5 | 7.5 |
| | | Prantij | 125 | 5266 | 42.13 | 18.7 | 14.9 |
| | | Talod | 2240 | 11638 | 5.20 | 41.3 | 1.8 |
| | | Vadali | 4295 | 17373 | 4.04 | 61.6 | 1.4 |
| | | Bayad | 2500 | 7522 | 3.01 | 26.7 | 1.1 |
| | | Total | 13204 | 73593 | 5.57 | 261.0 | 2.0 |
| 17 | Bharuch | Bharuch | 1735.30 | 11922 | 6.87 | 42.3 | 2.4 |
| | | Ankleshvar | 2760.10 | 306246 | 110.95 | 1086.0 | 39.3 |
| | | Jambusar | 1148.50 | 7359 | 6.41 | 26.1 | 2.3 |
| | | Amod | 572 | 4016 | 7.02 | 14.2 | 2.5 |
| | | Total | 6215.90 | 329543 | 53.02 | 1168.6 | 18.8 |
| 18 | Vadodara | Dabhoi | 2382.00 | 12092 | 5.08 | 42.9 | 1.8 |
| | | Karjan | 1527.00 | 9064 | 5.94 | 32.1 | 2.1 |
| | | Padara | 702.50 | 4200 | 5.98 | 14.9 | 2.1 |
| | | Chhotaudepur | 400.70 | 6462 | 16.13 | 22.9 | 5.7 |
| | | Savli | 1581.00 | 5872 | 3.71 | 20.8 | 1.3 |
| | | Total | 6593.20 | 37690 | 5.72 | 133.7 | 2.0 |
| 19 | Navsari | Navsari | 1804.95 | 19949 | 11.05 | 70.7 | 3.9 |
| | | Bilimora | 1520.25 | 9169 | 6.03 | 32.5 | 2.1 |
| | | Vijalpor | 367.30 | 3524 | 9.59 | 12.5 | 3.4 |
| | | Gandevi | 450.70 | 3629 | 8.05 | 12.9 | 2.9 |
| | | Total | 4143.20 | 36271 | 8.75 | 128.6 | 3.1 |
| 20 | Narmada | Rajpipala | 464.60 | 10632 | 22.88 | 37.7 | 8.1 |
| 21 | Valsad | Valsad | 1335.2 | 15911 | 11.92 | 56.4 | 4.2 |
| | | Pardi | 1310.43 | 9225 | 7.04 | 32.7 | 2.5 |
| | | Vapi | 2222.18 | 14153 | 6.37 | 50.2 | 2.3 |
| | | Umargam | 1273.05 | 9488 | 7.45 | 33.6 | 2.6 |
| | | Dharampur | 1551.15 | 18475 | 11.91 | 65.5 | 4.2 |
| | | Total | 7692.01 | 67252 | 8.74 | 238.5 | 3.1 |
| 22 | Surat | Tarsadi | 600.10 | 7466 | 12.44 | 26.5 | 4.4 |
| | | Mandavi | 760.20 | 8859 | 11.65 | 31.4 | 4.1 |
| | | Bardoli | 736.15 | 10116 | 13.74 | 35.9 | 4.9 |
| | | Kanakpur-Kansad | 700.30 | 9465 | 13.52 | 33.6 | 4.8 |
| | | Total | 2796.75 | 35906 | 12.84 | 127.3 | 4.6 |

| Sr. No. | District | Nagarpalika | Area of Nagar-palika (in Ha) | No of Trees | Tree/Ha | Tree cover (in ha) | Tree cover % of geographical area |
|---------|--------------------|--------------|------------------------------|----------------|--------------|--------------------|-----------------------------------|
| 23 | Tapi | Songadh | 569.20 | 8633 | 15.17 | 30.6 | 5.4 |
| | | Vyara | 792.15 | 17709 | 22.36 | 62.8 | 7.9 |
| | | Total | 1361.35 | 26342 | 19.35 | 93.4 | 6.9 |
| 24 | Gandhinagar | Dehgam | 1600 | 9178 | 5.74 | 32.5 | 2.0 |
| | | Kalol | 1724 | 60942 | 35.35 | 216.1 | 12.5 |
| | | Pethapur | 500 | 16011 | 32.02 | 56.8 | 11.4 |
| | | Mansa | 255 | 10086 | 39.55 | 35.8 | 14.0 |
| | | Total | 4079 | 96217 | 23.59 | 341.2 | 8.4 |
| 25 | Porbandar | Porbandar | 3110 | 204729 | 65.83 | 726.0 | 23.3 |
| | | Chhaya | 400 | 9153 | 22.88 | 32.5 | 8.1 |
| | | Ranavav | 137.50 | 5182 | 37.69 | 18.4 | 13.4 |
| | | Kutiyana | 125 | 2241 | 17.93 | 7.9 | 6.4 |
| | | Total | 3772.50 | 221305 | 58.66 | 784.8 | 20.8 |
| | GRAND TOTAL | | 212439.69 | 3244155 | 15.27 | 11504.1 | 5.4 |

Annexure - II: Distribution of trees in different girth classes in municipal corporation areas

| Girth class in cm | Municipal Corporations | | | | | | | | Total |
|-------------------|------------------------|-----------|---------|----------|--------|--------|----------|----------|-----------|
| | Gandhinagar | Ahmedabad | Surat | Vadodara | Rajkot | Rajkot | Junagadh | Jamnagar | |
| 10-30 | 220,150 | 119,030 | 97,730 | 269,690 | 38,870 | 38,870 | 18,350 | 7,420 | 917,620 |
| 31-60 | 306,310 | 153,310 | 150,620 | 234,140 | 56,140 | 56,140 | 26,870 | 13,670 | 1,121,410 |
| 61-90 | 212,890 | 154,690 | 66,330 | 148,170 | 26,140 | 26,140 | 15,060 | 12,870 | 737,110 |
| 91-120 | 81,360 | 78,870 | 13,450 | 47,040 | 9,110 | 9,110 | 6,890 | 4,860 | 262,320 |
| 121-150 | 27,410 | 56,730 | 3,850 | 27,130 | 3,780 | 3,780 | 4,280 | 2,950 | 138,860 |
| 151-200 | 14,370 | 32,530 | 1,610 | 13,270 | 1,980 | 1,980 | 3,640 | 2,130 | 80,570 |
| 201-250 | 2,870 | 14,150 | 390 | 5,280 | 770 | 770 | 900 | 1,130 | 28,080 |
| 250 -300 | 870 | 6,420 | 20 | 1,970 | 340 | 340 | 550 | 310 | 11,040 |
| Above 300 | 440 | 2,310 | 5 | 500 | 410 | 410 | 150 | 20 | 4,435 |

Note: Above figures have been rounded in tens

The graph (Fig. 9) representing distribution of trees in different girth reveal that the numbers of young trees are relatively less compared to the trees in middle and higher age or girth. Normally, the compositions of trees represent a normal distribution curve in natural areas, but in the municipal corporation areas, the trees having girth above 60 cm have normal distribution, except young trees having GBH between 10 to 60 cm, as the number in this girth class is low. Actually, the number of trees between 10 and 30 cm is only sixty percent of the number that is expected in case of normal distribution of trees in the girth classes. It is possible that enumerators ignored very young trees having GBH very close to 10 cm while enumerating them. In forestry, normally the trees having GBH over 30 cm are considered established ones for enumeration and the rest of young trees are never accounted in counting. Thus, Foresters normally ignore such big sapling or young tree/plants. Although the enumerators were asked to count such young trees, perhaps all such plants are missed in counting due to mind set of foresters. It is also true that the societies, colonies have been established in new areas at the cost of trees but they could not raise adequate number of trees due to lack of space. Old gardens, forest blocks and old tree groves have middle to old age trees which were raised a few decades ago. In some cities, the scale of plantation was good during the recent years but the survival percent was low.

Gandhinagar being a new city, established four decades ago, the number of very old and large trees is less. On other hand, number of large trees is relatively high in Ahmedabad as they were planted several decade ago before the Independence.

Distribution of trees in different girth classes in the eight municipal corporations

| Girth in cm | Number of trees |
|-------------|-----------------|
| 20 | 45,880 |
| 45 | 37,380 |
| 75 | 24,570 |
| 105 | 8,740 |
| 135 | 4,630 |
| 175 | 1,610 |
| 225 | 560 |
| 275 | 220 |
| 300 | 90 |

Graphic representation of tree distribution (Number of trees vrs GBH in cm)

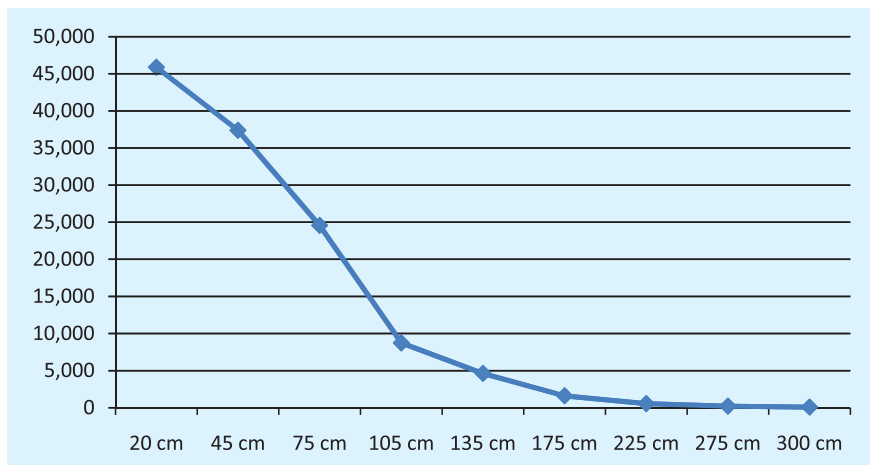


Fig. 9

Annexure - III: Trees in forest areas in the city of Gandhinagar and Bhavnagar

Trees in Indroda Park, Gandhinagar Municipal Corporation (Area 450 ha)

| No | Species | No of trees | No | Species | No of trees |
|----|---------------------------------|-------------|----|----------------------------------|----------------|
| 1 | Israel baval - Acacia tortalis | 37,617 | 7 | Gando baval - Prosopis juliflora | 4,438 |
| 2 | Deshi baval - Acacia nilotica | 29,447 | 8 | Bordi - Zizyphus mauritiana | 4,059 |
| 3 | Limdo-Azadirachta indica | 21,530 | 9 | Majeth - Dichrostachys cinerea | 2,819 |
| 4 | Gorad- Acacia senegal | 7,075 | 10 | Khijdo - Prosopis cineraria | 2,286 |
| 5 | Garmalo - Cassia fistula | 5,158 | 11 | Others | 14,070 |
| 6 | Kanji - Holoptelia integrifolia | 4,834 | | Total | 133,333 |

Trees in Victoria Park (Area 202 ha) in Bhavnagar Municipal Corporation

| No | Species | No of trees | No | Species | No of trees |
|----|---------------------------------|-------------|----|---------------------------------|----------------|
| 1 | Gorad- Acacia senegal | 180,178 | 7 | Subaval - Leucaena leucocephala | 1,565 |
| 2 | Gando baval-Prosopis juliflora | 14,474 | 8 | Limdo-Azadirachta indica | 931 |
| 3 | Ingorio - Balanites aegyptiaca | 4,765 | 9 | Khati amla - Tamarindus indica | 915 |
| 4 | Deshi baval - Acacia nilotica | 2,390 | 10 | Vikado - Maytensus emargianata | 445 |
| 5 | Kanji - Holoptelia integrifolia | 2,389 | 11 | Others | 2,260 |
| 6 | Hermo - A. leucophloea | 2,209 | | Total | 212,521 |

Gorad, small size tree, dominates the forest in Victoria Park. The tree density of this forest is 1052 tree/ha. In fact Gorad constitutes about 85 % of total trees in the park.

Annexure - IV: Tree Population in Municipal Corporation Areas to meet minimum standard of tree cover

| No | Municipal Corporation | No of trees | Species | No of trees |
|----|-----------------------|--------------|--------------|--------------|
| 1 | Ahmedabad | 6.18 | 19.89 | 13.71 |
| 2 | Surat | 3.33 | 16.65 | 13.32 |
| 3 | Vadodara | 7.47 | 7.47 | -- |
| 4 | Gandhinagar | 8.67 | 8.67 | -- |
| 5 | Rajkot | 1.38 | 4.41 | 3.03 |
| 6 | Bhavnagar | 4.76 | 4.76 | -- |
| 7 | Junagadh | 0.77 | 2.41 | 1.64 |
| 8 | Jamnagar | 0.46 | 1.45 | 0.99 |
| | Total | 33.02 | 65.71 | 32.69 |



Plant trees
for
a better tomorrow



Harihar van at Somnath



Gujarat Forest Department