

Assessment of Status and Carbon Sequestration Potential of Green Cover in the Major Urban Development Authorities of Gujarat

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Abstract

Urban forest and tree cover play a fundamentally important role in improving the environmental quality, energy efficiency, aesthetic appeal, biodiversity, and regulating the climatic hazards. The study area encompasses the 8 major urban development authorities of Gujarat which has observed a population increase from 0.59 crore in 1981 to 1.66 crore in 2011, which is projected to increase to 2.01 crores as of 2021. The per capita CO₂ emission was recorded to be 1.6 tons/annum in 2011 and is expected to rise to 2-2.5 tons/annum by 2021. The average rate of conversion of land in Gujarat for non-agricultural and non-forestry uses is about 4,000 ha per year leading to the severe defacement of the green cover. In this study, an assessment and evaluation of the area under the urban forest & tree cover and its respective carbon sequestration potential is done for the base year (2011) and an attempt is being made to calculate it for the year 2021 using the standard protocols. As of 2011, about 64.31 lakh trees of about 230 species above 10 cm girth at breast height was enumerated in the study area. The study highlights that the green cover inclusive city planning, stakeholder's coordination, use of native tree species, compensatory afforestation mechanism, protection of the existing green areas, and employment generation through GIM and MNERGA schemes in the social and agro forestry plantations can enhance the overall green cover in the urban agglomerations of Gujarat. As a result, the total tree number in the study area can be increased from 64.13 lakhs (2011) to 143.7 lakhs (2021) and the carbon stock can be enhanced from 12.86 lakh tonnes of carbon in 2011 to 28.74 lakh tonnes till 2021. For achieving the desired targets, the land under the plantation has to be increased from 23,760 ha in 2011 to 55,158 ha till 2021. Hence, enhancing urban tree and forest cover can give plausible solutions to the infinite woes of socio-economic, ecological, and environmental sustainability of the urban areas of Gujarat.

Keywords: Urban Green Cover, Carbon Sequestration, Climate Change, Social Forestry, and Agro-forestry.

1. Introduction

The rapid urbanization of cities in India has led to over exploitation of natural resources, exponential increase in pollution, and accumulation of greenhouse gases in the atmosphere.

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Carbon emission due to deforestation and use of fossil carbon has brought forests to the center-stage of climate change mitigation strategies. As per MoEF (2014), India has a spatial extent of the urban tree cover on 12,790 Km² (16.40 %) out of the total urbanized area of 77,997 Km² as on 2013. The National Forest Policy, 1988 envisions average forest and tree cover of 33 % for the plains and 66.66 % for the hilly areas of the country. About 7.48 % of the geographical area of Gujarat has been declared as forest which is much less than national forest cover of 21.23% (FSI, 2013). Average population density of Gujarat is about 308 persons/Km² which is the root cause of resource depletion, environmental pollution, urban heat island effect, loss of forest & biodiversity, etc. There is an urgent need for the planned development of the urban areas to present the picture of green and clean cities with adequate forest & tree cover, parks, lakes, wetlands, urban biodiversity, nature education centers, etc. The selected 8 urban development authorities' of Gujarat supports a population of 1.66 crore as of 2011 with the third highest urbanization rate after Tamil Nadu and Maharashtra. As per the Arithmetic-Geometric method of Projection, it is estimated to increase to 20.18 crore by the year 2021. Investment patterns on infrastructure, employment, and civic amenities are the most crucial factors leading to the urbanization in the urban growth centers of Gujarat. As per Census data of 2011, the population of AUDA constitutes 10.77 % of the state's population. Similarly, GUDA constitutes 0.37 %, SUDA constitutes 8.27 %, VUDA constitutes 3.45 %, RUDA constitutes 2.30 %, JADA constitutes 0.88 %, JUDA constitutes 0.53 %, and BADA constitutes 0.98 %.

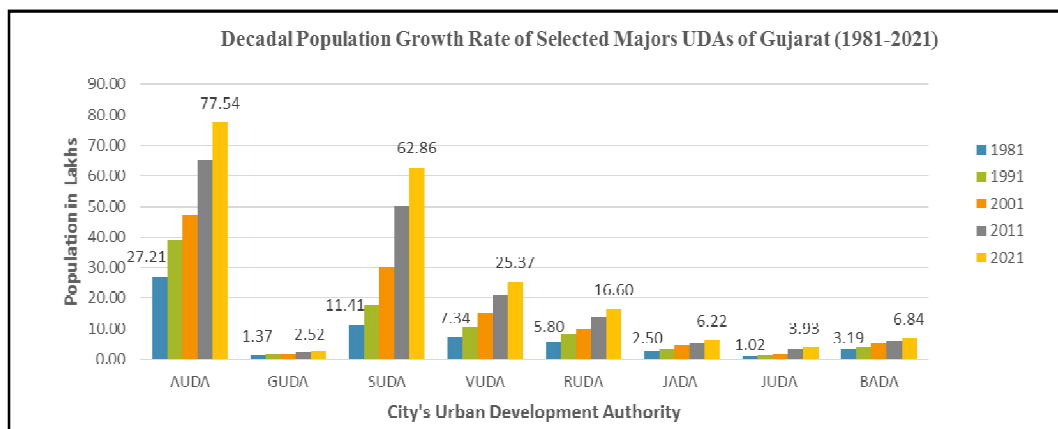


Fig. 1: Decadal Population Growth Rate in the Study Area (1981 -2011).
 Projected for the Year 2021

About 29.51 crore trees have been estimated in the non-forest areas of Gujarat in and around the villages, whereas about 63.34 lakh trees are estimated in the urban areas. About 8 municipal corporations and 159 municipalities along with their satellite areas supports about 64.13 lakh trees contributing to 2.44 % of Trees Outside Forest (TOF) area. Recent tree counting of 2013 estimates the density of 18.5 trees/ha in TOF as compared to 14.1 trees/ha in 2003. There is an increase of 4.82 crore trees in the ten years period at an average annual rate of 48.2 lakh trees but with poor survival rate due to semi-arid and other stressful environmental conditions. The average tree density for the study area was found out to be 20.03 trees/ha due good tree cover in the villages surrounding Vadodara and Gandhinagar. In rural Gujarat, 64% fuel wood is collected from the forest and trees adjoining urban areas,

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whereas only 12.7 % is purchased, and the remaining 23.3 % is obtained from the field and private lands. Hence, there is a need for sustainable management of forest and tree cover outside forest areas for meeting ecological, social, and economic needs of the society.

2. Study Area Profile

The study area encompasses the 8 major Urban Development Authorities around the municipal corporations of Gandhinagar, Ahmedabad, Rajkot, Surat, Vadodara, Bhavnagar, Junagadh, and Jamnagar which covers 3.10 lakh ha (1.58 %) of the state's geographical area. Climate of the study area is moderate with mean temperatures ranging from 9° C to 47° C and the average annual rainfall ranging from 550 to 1100 mm. The soil type ranges from sandy alluvial, coastal alluvial to deep black soil. The livestock population of the state is 23.52 million (Livestock Census, 2007) with high pressure on existing vegetation and fodder resources. Substantial human-induced environmental changes are linked to urbanization, hence urban landscapes of Gujarat accounts for over 3/4th of total carbon emissions, 3/5th of the residential water consumption, and 3/4th of the industrial wood consumption.

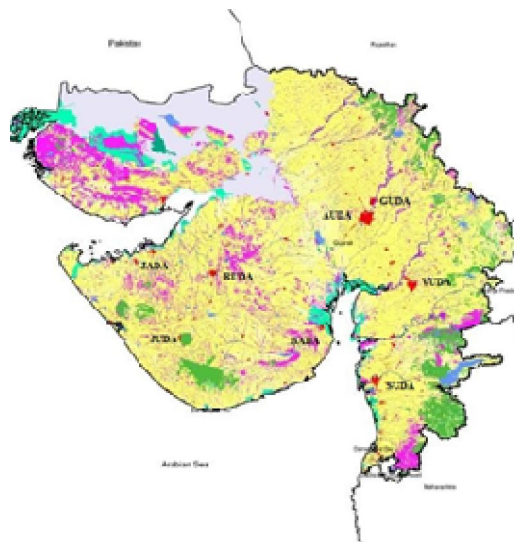


Fig. 2: Locations of the 8 Major Urban Development Authorities in Gujarat.

As of 2011, the study area had a forest and tree cover in 23,760 ha (7.41 %) out of 3, 10, 000 hectares total area with an average tree density of 20.3 trees/ha. As per the norms of the National Institute of Environmental Studies, New Delhi, the tree cover should be at least 15 % (20 m² /person) for megacities with a million plus population.

Enumeration of the total number of trees above 10 cm GBH during 2011 indicates that about 9.17 lakh (27.92 %) of trees were having GBH in 10-30 cm girth class, whereas only 0.15 lakh (0.48 %) trees were having GBH > 250 cm. Similarly, in the mid aged classes 11.21 lakh (34.12 %) trees were having GBH of 31-60 cm, 7.37 lakh (22.00 %) trees were having GBH of 61-90 cm, 2.62 lakh (7.96 %) trees were having GBH of 91-120 cm, and 1.38 lakh (4.22 %) trees were having GBH of 121-150 cm. In older trees age classes, about 0.80 lakh (2.45 %) trees were having GBH of 151-200 cm and 0.28 lakh (0.85 %) trees were having GBH of 201-250 cm.

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Table 1: The Spatial Coverage of the Green and Agricultural Land in the Study Area.

Urban Bodies	Number of Villages	Total Area (ha.)	Agricultural Area (ha.)	Green Area (ha.)	Tree density/ha.
GUDA	39	38,000	31,750	8,019	58.25
AUDA	67	59,375	37,121	2,820	13.40
RUDA	54	56,224	35,444	590.5	2.96
SUDA	94	32,651	2,968	1,647	14.23
VUDA	98	55,200	24,769	6,435	32.87
BADA	15	13,147	7,473	800	13.76
JUDA	40	30,722	1,229	1,331	12.04
JADA	26	24,142	241	2,137	12.77
Total	433	3.10 Lakh ha.	1.41 Lakh ha.	0.23 Lakh ha.	Average:20.3

3. Methodology

The given study is an amalgamation of the literature review, field visits, qualitative and quantitative analysis of the data on spatial coverage of the urban green cover in the study area and its respective carbon sequestration potential. Based on the above findings, the study recommends percentage achievable area under forest and tree cover through appropriate policies, plans, and managerial interventions till 2021.

3.1 Status of the Tree and Green Cover

The quantitative database of the trees above 10 cm girth at breast height for the study area was extracted from the research reports, publications, web sources, and the social forestry wing of the Gujarat Forest Department. Based on the available quantitative database, the total area of the urban development bodies in hectares, their relative area under forest and tree cover, its percentage, and density per hectare was then calculated by using arithmetic operations of the algebra. The trees were divided into different girth classes after measuring their Girth at Breast Height (GBH) using measuring tape by the staff and research team of the social forestry wing. The division of girth classes was done in 10-30 cm, 31-60 cm, 61-90 cm, 91-120 cm, 121-150 cm, 151-200 cm, 201-250 cm, 250-300 cm, and > 300 cm classes respectively. The given exercise facilitated the classification of average carbon sequestration potential of trees by their girth class encountered in the study area. Their organic carbon content of the common species was found out in the laboratory of Anand Agricultural, University, Gujarat.

3.2 Carbon Sequestration and its Stock

The IPCC (2003) good practice guidance of LULUCF method was used to estimate the amount of carbon stored in living biomass of enumerated urban trees in tons Carbon/year. Carbon sequestration potential of the total number of enumerated trees is calculated using Gujarat specific annual biomass increment, area under tree cover, default average above ground biomass growth factor (7.1), Gujarat specific ratio of AGB/BGB (0.26), average annual above and below biomass growth (8.94 tonnes dm/ha/yr.), and Carbon fraction of the dry matter (0.5).

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The annual increase in Carbon stocks due to biomass increment in forest land is calculated using the below formula:

1. $G_{total} = G_w \times (1+R)$
2. $\Delta C_g = A \times (G_{total} \times CF)$

Where,

G_w -Average annual above ground biomass growth (7.1)

R - Ratio of below ground biomass to the above ground biomass (0.26 Gujarat Specific Value)

G_{total} -Average annual biomass growth above and below ground (8.94 tonnes dm/ha/year)

ΔC_g - Annual increase in Carbon stock due to biomass increment (tons carbon/year)

A -Area under tree cover in hectares (ha)

CF -Carbon fraction of the dry matter (0.5)

The given exercise has helped to estimate the changes in the carbon stock and CO₂ removals associated with changes in biomass and soil organic carbon pools on forests and lands converted into forest land naturally or with the management interventions of the forest department.

4. Result and Discussion

4.1 Strategic Tree Plantation Requirement

Based on the comparative analysis and preliminary calculations on the number of trees for 2011, RUDA requires maximum plantation of 18.15 lakh trees to bring its 10 % area under forest and tree cover during the decadal time period from 2011-2021. BADA requires the least number of trees i.e., 5.08 lakh due to the presence of Victoria Park having good tree cover and density within city limits. GUDA requires 11.60 lakh additional trees to increase its 20.65 % geographical area under green cover to 25 % till 2021. Similarly, AUDA requires 12.93 lakh, SUDA requires 6.77 lakh, VUDA requires 11.03 lakh, JUDA requires 7.09 lakh, and JADA requires 6.74 lakh trees respectively to bring their 10 % of the geographical area under forest and tree cover till 2021.

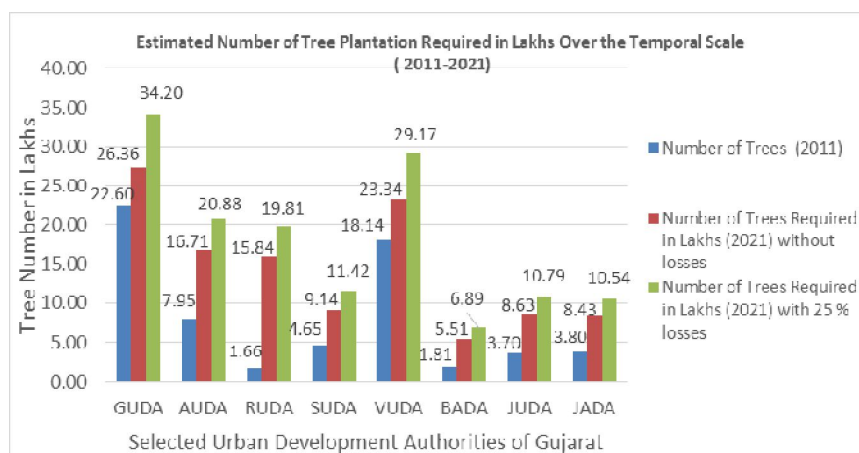


Fig. 3: Tree Plantation Required to Achieve the Desired Target over a Decade Period (2011-2021).

4.2 Annual Carbon Sequestration Potential (2011-2021)

Research estimate shows that India’s forest and tree cover of 78.29 million ha (23.81 %) is capable of neutralizing 11.25 % of India’s total GHG emissions (Kishwan, 2009). The rate of carbon sequestration is estimated to be 7.86 kg carbon/tree/year for the average of India. The corresponding average value for Gujarat is estimated to be 12.91 kg carbon/tree/year. A total of 1, 06,281 tons of Carbon (3,90,051 tons of CO₂ equivalent) was removed annually in 2011 by about 64.13 lakh trees within the study area of the 8 selected urban development authorities. It can be enhanced to 2,46,721 tons of Carbon (9,05,466 tons of CO₂ equivalent) per annum by ensuring the survival of 115 lakhs saplings from the total plantation of 143.7 lakh saplings (incurring 25 % stressful condition loss) by 2021. The average rate of carbon sequestration varies from 1.0 kg/year in tree having 20 cm GBH to 93 kg/year having 240 cm GBH.

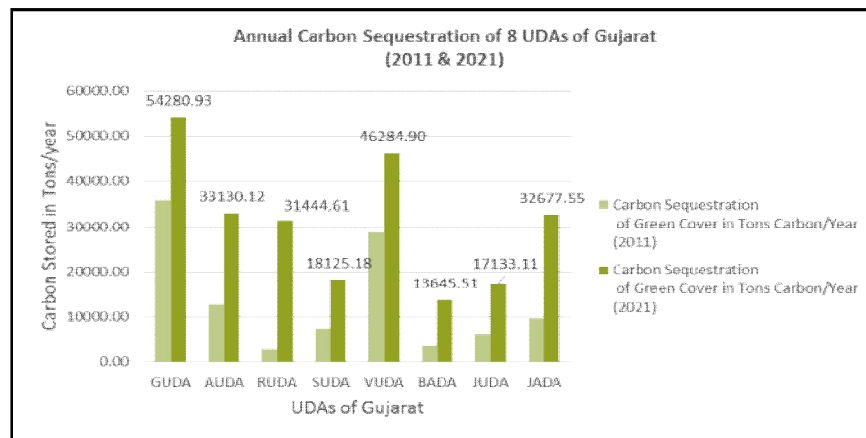


Fig. 4: Annual Carbon Sequestration in the Study Area in 2011 and in 2021.

It has been found that, an average of about 950 Kgs of Carbon is sequestered and stored in the living biomass of trees at or above 350 cm GBH during its entire lifespan. Contrary to it, an average Carbon sequestration potential of 10-60 cm GBH Trees is only 29.6 Kg/Tree in its lifespan. Hence, it is necessary to conserve old and heritage trees due to their higher carbon pool, ecological, and cultural values.

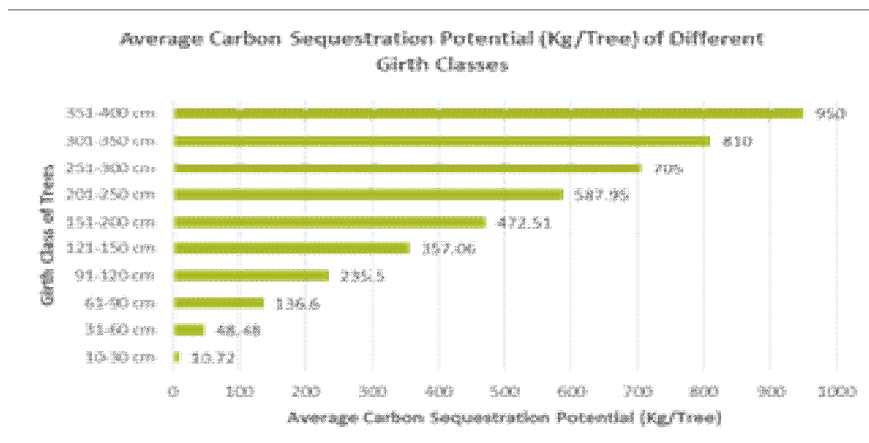


Fig. 5: Average Carbon Stored in the Trees of Different Age Classes (Entire Lifespan)

4.3 Annual Land Requirement (2011-2021)

Based on the comparative analysis and preliminary calculations of the geographical area under green cover in 2011, GUDA will require to add plantation in about 4,116 ha of additional land to bring 25 % of its geographical area under the tree and urban forest cover. RUDA requires maximum land of 6,439 ha. to bring its 10 % land area under green cover from 2011-2021 with strict adherence to the set targets due to poor tree cover, water scarcity, and land crunch. BADA requires the least amount of land, i.e. 2,250 ha due to presence of Victoria Park having good tree cover and tree density of 1,052 trees/ha. Similarly, AUDA requires 4,586 hectares, SUDA requires 2,405 hectares, VUDA requires 3,912 hectares, JUDA requires 2,519 hectares, and JADA requires 5,168 hectares of land respectively to bring their 10 % of the geographical area under green cover till 2021.

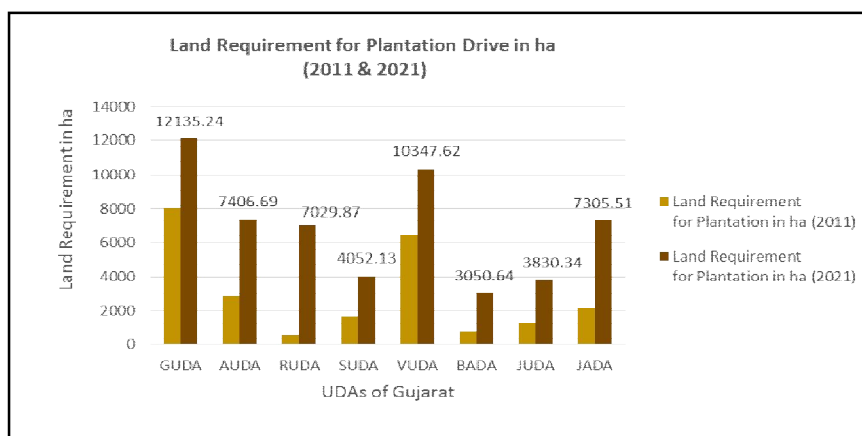


Fig. 6: Land Requirement in the Study Area in 2011 and in 202.

5. Recommendations

5.1 Scientific Long Term Planning

Urban green and tree cover should form an integral part of the development of the master plans of the cities and its successive long term management. Resource assessment with respect to water availability, soil type, existing tree species, their density & health, growth conditions, etc. should be done to minimize stressful conditions and ensure long term survival of the selected species. Use of modern scientific tool like GIS wherein the given area can be divided into 1 Km² x 1 Km² or 5 Km² x 5 Km² uniform grids for planning of afforestation schemes should be done to attain the uniform results.

5.2 Agroforestry in Urban Agglomerations

It is a component of social forestry, the success of which is dependent on the economic returns from the land under plantation. To compete with agricultural crops, high quality clonal or tissue culture seedlings should be supplied to farmers for plantation e.g., Neem (*Azadirachta indica*), Arduza (*Ailanthus* sp.), Mango (*Mangifera indica*), etc. Inclusion of trees in farming systems of rural and peri urban landscape can enhance productivity, profitability, diversity, and ecosystem sustainability. Since, the current estimates show that about 64 % of country's timber requirement is met from trees grown on farms, it has huge potential of generating jobs in production, industrial applications, and value added ventures. It can augment energy capacity through biomass, bio-char, and bio-gas production.

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5.3 Provision for the Economic Incentives

The agriculture department and the forest department have come up with the scheme under which a cash subsidy of Rs 20,000 per year for a period of five years is provided to the land owners permitting forest departmental plantation at the rate of 1,000 trees/hectare. If the tribal people permit planting of 2,000 trees on one hectare of land in a tribal area, they are given Rs 5,000 per month per family. Further, the government had decided to pay Rs 60,000 per annum in the tribal areas to prevent rampant cutting of the forests.

5.4 Biodiversity Parks and Tree Tourism

Biodiversity Parks should be created in each of the urban development body with a population of more than 5 lakhs. Tree tourism has the potential to attract nature enthusiast and biodiversity lovers to map the biodiversity in the urban agglomerations of the cities for their ecological, educational, research, and aesthetics purpose. It has the potential to generate revenues which can help in the conservation of green cover and heritage trees, generate employment, and ameliorate the local biodiversity.

5.5 Raising of Tall Seedlings

Tall seedlings of ecologically and economically important species should be raised so that plantations grow fast within three years and the success rate of plantation is also improved. From 1971 to 2011, a total area of 25, 180 hectare land was afforested by planting over 34.95 lakh seedlings in the urban areas of Gujarat. Besides, there are 22 clonal production centers of high quality seedlings which produces about 171.5 lakh clonal plants of Eucalyptus, Teak, Casuarina species, etc.

5.6 Tree Plantation Campaign

Green Gujarat campaign should be undertaken by involving civic society, schools, colleges, institutions, NGOs, tree lovers, and farmers to create mass movement for tree planting and their subsequent care. Urban development authorities should earmark a certain percentage of their budget for raising tall trees as advised by the forest department of Gujarat. The Gujarat Urban Development Department advocates people's participation, NGOs, and civic society for the creation of Panchavati, Smriti Van, Sanskriti Van, Oxygen Park, Green Guards, etc. The Nagar Nandan Van Yojana afforestation program distributed about 6.33 lakh tall seedlings to the people for the plantation since 2011. The notification of the Gujarat Urban Development Department of November, 2009 emphasizes the plantation of minimum of 10 trees by every section of classes in the school.

5.7 Guidelines for Tree Felling, Looping, and Pruning in the Urban Areas

Tree cutting should be strictly regulated by Saurashtra Felling of Trees (Infliction of Punishment) Act, 1951. Prior permission from the Revenue office or Tehsildar is mandatory under the provisions of the act. Authority should be given to the urban local body officials along with forest departmental officers to fine defaulters on the spot. It is notable to mention that, tree species like *Eucalyptus spp.*, *Casuarina spp.*, and *Prosopis juliflora*, etc. are exempted from the felling permission.

6. Conclusion

Gujarat has been recording an impressive decadal urban population growth rate of 35.83 % against the national average of 31.80 %. In the backdrop of shrinking land and water resources

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for urbanization and conventional agriculture practices, it may be difficult to bring 15 % of land area (20 m²/inhabitant) under green cover (excluding GUDA & VUDA), but 7-10 % (10-15 m²/inhabitant) seems to be achievable target till 2021. It has been evaluated that, GUDA and VUDA has high tree density (above 30 trees/ha) with high carbon sequestration potential. AUDA, SUDA, BADA, JADA, and JUDA has low tree density (12-15 trees/ha) with average carbon sequestration potential. RUDA has very poor tree cover with tree density of 2.96/hectare only. The study area has huge untapped Agroforestry potential in the 433 villages encompassing 1.40 lakh hectare (45.48 %) agricultural area. It has potential to meet 64 % of Gujarat's timber requirement and generates 450 labor-days/ha/year.

The free tree sapling distribution under Nagar Nandan Van Yojana and Van Mahotsav has resulted in plantation of 26 lakh saplings with an investment of 41.96 crore from the year 2005 till 2011. Appropriate share of Gujarat from the central fund of Rs. 75,000 crore for urban area development (2012-2017), GIM fund of Rs. 13,000 crore, CAMPA fund of Rs. 23,608 crore, and dedicated MNERGA plantation fund of Rs. 500 crore/year can be leveraged for enhancing the urban green cover. Massive afforestation drive in Gujarat has resulted in an annual increment of 37.68 MT of carbon or 138.15 MT of CO₂eq in the urban forest and tree cover of Gujarat.

For the developing country like India and economically prosperous state like Gujarat, green cover is an inevitable path to foster the green infrastructure of the urban agglomerations of the cities. Hence, economically attractive agroforestry plantation, use of high quality clonal seedlings, development of Gram Vans (village forests), plantation on panchayat land, wastelands, roads, canal, schools, colleges, etc. can provide the attractive and plausible solutions. Uniform scientific and technological standards for urban forestry, research, training, appropriate species selection, financial mechanism, and co-ordination between different stakeholders has the potential to improve the overall urban forest and tree cover in the Gujarat.

Farmer friendly financial and institutional mechanism and periodic training by agriculture & forest department can ensure the desired penetration of the scheme amongst different stakeholders. It can ensure average annual growth of 4 % in agriculture productivity along with meeting the plantation targets set for the urban forestry. It is expected that improving the tree cover in non-forest areas of Gujarat will improve the green cover from 269 million to about 350 million in the coming ten years (2011-2021) marking its commendable achievement.

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