



Tree, People and City: A study on Green covers of rapidly urbanizing Mangalore city

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Abstract

Steady increase in population and automobiles on the streets and lack of vision and planning has made cities denser and compact with ever diminishing the much needed green spaces. Green cities have become a utopian concept. Increase in global warming and creation of Urban Heat Islands have become common. In India trees are given Ethical, Social and Emotional dimension but conversely, trees and green spaces are neglected by the Urban Developers and Law Makers. Since 1980's, there was a wide approach towards sustainable cities, making cities from gray to green but here also role of green spaces was limited to "city beautification". Trees are an important asset for ecological sustainability and biodiversity. Mangalore is perched strategically on the threshold of a "smart city". This study gives an account of the green cover present in the city of Mangalore, highlighting the importance of green zones in major cities not only for its aesthetic appeal but also for benefits they provide to environment and human population.

Key words: *Global warming, Green cover, Urbanisation*

INTRODUCTION

In the beginning of 20th century, only one tenth of the global population was living in the cities which now has exceeded 50 percent. This is expected to increase further in future. With the rapid urbanization there has been an increase in the level of air pollution and global temperature and a steady decrease in green cover of the city. According to a report by "Save the Children", every fourth child living in urban India, fall sick every month on average because of low immunity. Contamination of ground water and increase in the level of air pollution has damaged immune system of children. Doctors associate high levels of suspended particulate matter and sulphur dioxide with increased mortality, morbidity and impaired pulmonary function.

The average green space area per capita and green space ratios are mainly two statistical indexes for quantifying green cover of the city. In 19th century, some experts had put forth a rule, the average volume of carbon dioxide exhaled by city residents as a standard for determining the green space area per capita and accordingly a 50 m² green space per person was proposed. In 20th century, experts in Germany, Japan and other countries proposed a 140 m² suburb forest area per capita or a 40 m² urban green space per inhabitant as standard for reaching a balance between carbon dioxide and oxygen, to meet the ecological balance and compensating human intervention. Some of the developed countries have adopted green space of 20 m² park area per capita as a general standard. World Health Organization suggests ensuring at least a minimum availability of 9 m² green open space per city dweller. Ecological and Environmental Organizations of United Nations had put forward a standard of 60 m² park area per person as the best living standard for urban environment (Xiao-Jun 2009).

Current challenge in an urban city is to provide clean air and healthy living through conservation and restoration of urban green spaces. Trees in an urban system helps in maintaining the ecosystems by conserving the biodiversity by removing atmospheric pollutants, carbon sequestration, recharging oxygen back to the environment, reducing urban noise, mitigating urban heat island effects and regulating microclimate (Bolund, 2009). Trees helps in improving environment and quality of life in the city.

An urban green space comprises of urban parks, forests and related vegetation. The term "urban trees" includes trees growing both within the built environment as well as road-side avenues and public places in urban systems. These add value to the inhabitants in an urban area. Forests Act says 30% of minimum forest cover should be maintained by a state. In India, master plan of a city suggests approximately 20 to 30% coverage of the total geographical area for green spaces. According to FSI Report of Delhi 2009, as per population data 2001, average tree and forest cover is about 20% of geographical area and about 21 m² /inhabitant. From 2001, population in



Delhi has increased and is projected to increase rapidly in future. Services such as enormous housing development, industrial and infrastructure development etc. has come at the cost of trees. is provided at the cost of trees. But according to a report published (Apr 16 2015 : The Times of India, Delhi) over one lakh trees were cut during 2006 - 2014 to make way for Delhi Metro and PWD projects, bringing down the city's green cover to 10%. Metros and Highways have led to massive deforestation. Bangalore and Delhi are best examples for this. The green cities of 1980's with green cover of 71% changed to 17% in just three decades. Gray cities with huge concrete covered ground are creating urban heat islands and making cities unlivable. Practical solution for reviving and revitalizing the city is by reducing the rate of deforestation for city services. Growing more trees in the cities will hence control the carbon level of atmosphere. This can be achieved only by mutual support and co-ordination at different levels from law makers, planners and designers to the common public at an individual level.

Urban dwellers are dependent on motorized vehicles. Increase of private vehicles in cities, have increased the level of carbon emission. New Delhi recently was in news for its increased air pollution where more than its 16 million inhabitants are exposed to severely high pollutant concentrations on an annual average basis. It is in this regard that the Government of Delhi came up with a strategy of introducing Odd-Even scheme in which privately owned cars were restricted to run on the roads on alternate days based on the last digit (odd/even) of the registration number. The Delhi government's scheme was an important move in opening a debate on long-term solutions to India's urban problems. Urban environments are an opportunity as it contributes the maximum in nation's growth and development. Here lies the importance of implementing effective policies and guidelines for the protection of public health. Although studies show that odd-even scheme did not work in the sense of marginal reduction in air pollution (Analysis by Council on Energy, Environment and Water), but it was a clear success in a political sense and policy level that urban cities of India need more attention to improve the air quality and that is what urbanizing cities need right now.

Urban planners and designers pay more attention in providing public transport system and discouraging private vehicles, improving the traffic congestion of the city but rarely focus on improving the air quality by increasing green cover of the city. Trees can lock up large amounts of carbon in their wood. This is called Carbon Sequestration. Carbon sequestration is a mechanism for the removal of carbon from the atmosphere by storing it in the biosphere. Trees play an important role in the global carbon cycle by sequestering a substantial amount of carbon dioxide from the atmosphere.

STUDY AREA

Mangalore, one of the fastest growing metropolitan city in India, is the administrative headquarters of the Dakshina Kannada district. The city is on the west coast of the Karnataka state and is the largest of all the eight-urban centers of the district. Mangalore is also the fourth largest city in terms of population in the state. Mangalore has been selected as one of the Smart Cities to be developed under the Ministry of Urban Development (MoUD), Government of India's Smart City Mission. Smart city concept (SCC) talks about improving livability, sustainability and economic development of the city but SCC gives more emphasis on quantitative scaling of infrastructure and services in terms of transportation, water supply and waste disposal. Action plans and strategies have neglected the qualitative improvement of the city by providing more green spaces and conserving the existing green cover of the city.

The Urban Heat Island is a phenomenon where temperatures in urban areas are warmer than the surrounding rural countryside. This is because more heat has been trapped by concrete structures of the city including roads and buildings. Studies on microclimate formation through built-up morphology and urban shade trees have clearly established the importance of urban trees in alleviating the heat island effect in a hot and humid climate (Bar, 2009). The climate variability in Karnataka was analyzed in 2010 by the India Meteorological Department (IMD) by analysing daily rainfall data for the period of 1971–2005. Climatic Research Unit (CRU) data for the temperature for the period 1901–2002 shows that the Coastal Karnataka districts have an average rainfall of >25 mm/day. Decrease in precipitation trend has been observed in Coastal Karnataka. Rainfall has decreased by 17.69 mm/day/100 year in Mangalore. There is increase in minimum temperature by 0.141 °C/100 year and increase in maximum temperature by 0.148° C/100 year in Mangalore (Singh, 2010). As urban green spaces and urban forests decrease, evapotranspiration rate decreases. Thus, a common measure to mitigate urban heat island effect is to increase urban green spaces.



Mangalore Landsat 8 Annual EVI Composite

Mangalore Landsat 8 Annual EVI Composite

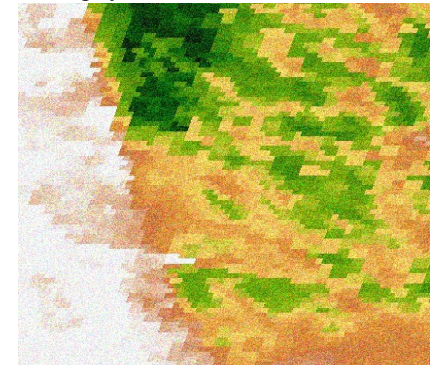
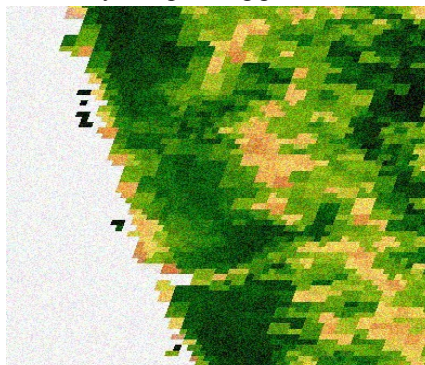
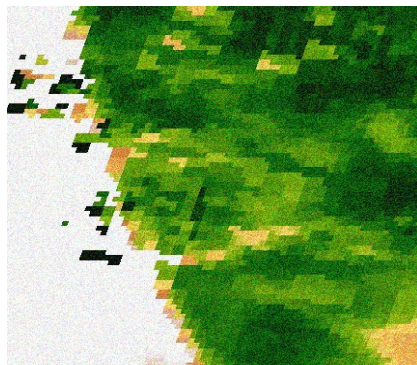
The Enhanced Vegetation Index (EVI) is generated from the Near-IR, Red and Blue bands of each scene, and ranges in value from -1.0 to 1.0. These composites are created from all the scenes in each annual period beginning from the first day of the year and continuing to the last day of the year. All the images from each year are included in the composite, with the most recent pixel as the composite value.

Figure 1: Mangalore Land Sat Images

Images taken: October 13, 2016, Source: Google Earth Engine

Landsat 8 image composites made from Level L1T orthorectified scenes, using the computed Top-of-Atmosphere (TOA) reflectance are taken to analyse the change in green cover of the city. The two MODIS VIs,

the normalized difference vegetation index (NDVI) and enhanced vegetation index (EVI), are produced globally over land at 1 km and 500 m resolutions and 16 day compositing periods. NDVI is chlorophyll sensitive and EVI



Mangalore MODIS Terra Daily NDVI image, 2008

Mangalore MODIS Terra Daily NDVI image, 2012

Mangalore MODIS Terra Daily NDVI

The Normalized Difference Vegetation Index is generated from the Near-IR and Red bands of each scene as $(NIR - Red) / (NIR + Red)$, and ranges in value from -1.0 to 1.0. This product is generated from the MOD09GA MODIS surface reflectance composites.

Figure 2: Mangalore Land Sat Images, Data availability (time): 2008 - 2016

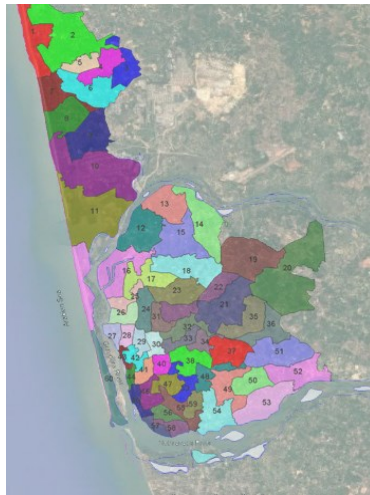
Image taken: October 13, 2016, Source: Google Earth Engine

is more responsive to canopy structural variations, including leaf area index (LAI), canopy type, plant physiognomy, and canopy architecture.

METHODOLOGY

A study was carried out in July, 2016 to calculate Carbon Sequestration by trees in the 37 acres of St Aloysius College campus. Aerial view of the college campus projected around 11 acres canopy of green vegetation in the campus. Total number of trees in the campus was counted to 1730. The carbon sequestration capacity of a tree species depends upon its age, height, girth size, biomass accumulation capacity, canopy diameter and most important wood specific density. So it would vary with species to species and tree to tree. An approximate range of Carbon Sequestration was calculated by measuring Tree height, Girth size and Biomass Accumulation Capacity. Total carbon storage was determined to be 332000 kg and total Carbon sequestration rate was found to be 6640 kg/year.

This study was taken as a live sample study and tried to compare and relate with broader city level. A “Point to whole” approach was taken for the study of this project. Tree with its canopy (spatial extent) were covered using vector mapping in GIS using better resolution data (Google Earth).



Mangalore Ward Map

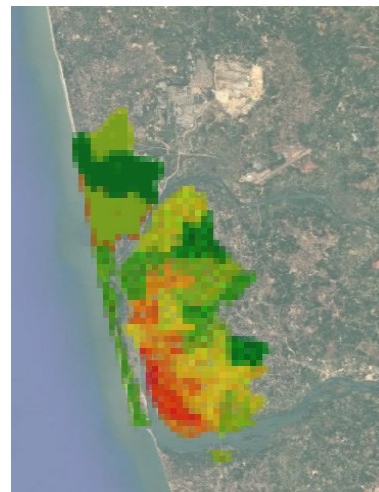


Area of study region :

ANALYSIS



Tree canopy coverage



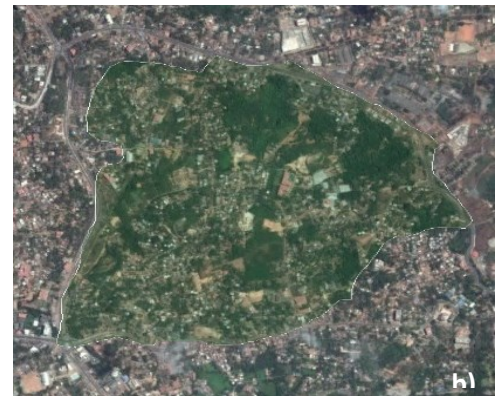
Spatial distribution of green cover
(Refer table 1)

Table 1

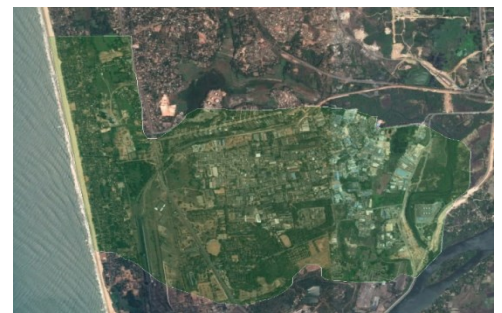
Ward no.	Population (2011)	Area (sq.k m)	Approx green cover (%)	Per capita green space (m ² /inhabitant)	Approx. Carbon sequestration (kg/year)
9	10,649	4.13	21.79%	84.51	130271.47
10	7,503	7.07	25.77%	242.83	164833
11	9,930	4.48	12.95%	58.42	83986.82
12	8,555	2.42	17.61%	49.81	38715.28
13	8,615	1.3	27.01%	40.76	31884.02
15	7,137	2.75	33.44%	128.85	79644.92
16	11,781	3.14	34.17%	91.07	155440.02
17	10,393	0.9	15.67%	13.57	12620.46
18	11,781	3.42	23.02%	66.83	66213.98
22	10,955	2.43	46.23%	102.55	98532.18
23	10,096	2.45	25.35%	61.52	55503.96
24	9,367	1.86	21.24%	42.18	35965.41
25	8,253	0.46	22.43%	12.5	9378.5
26	9,023	0.43	22.86%	10.89	8828.53
27	7,077	0.52	24.51%	18.01	11741.94
28	6,741	0.57	17.48%	14.78	9016.68
29	6,650	0.51	17.91%	13.74	8235.14
30	6,380	0.5	13.62%	10.67	6122.08
31	8,370	0.5	34.08%	20.36	15297.96
32	7,158	1.35	43.60%	82.23	53998.76
33	6,497	1.05	40.23%	65.02	36674.58
34	6,396	0.62	43.48%	42.15	24256.75
37	7,797	1.82	59.11%	137.98	95463.91
38	7,322	0.78	32.29%	34.4	21752.92
39	7,740	0.63	19.91%	16.21	11752.08
40	6,917	0.59	20.85%	17.78	10753.44
41	5,829	0.71	8.86%	10.79	5615.52
42	7,149	0.48	15.68%	10.53	6556.27
43	6,250	0.29	13.34%	6.19	3878.76
44	6,749	0.21	3.44%	1.07	651.29
45	7,449	0.5	10.68%	7.17	5137.92
46	6,908	0.64	9.14%	8.47	8148.3
47	7,998	0.9	10.71%	12.05	13633.57
48	8,509	1.17	14.52%	19.97	24256.75
49	9,350	1.38	24.74%	36.51	49671.34
54	7,314	1.91	24.14%	63.04	66416.6
55	8,398	1.09	11.37%	14.76	17729.43
56	8,216	0.47	10.63%	6.08	7250.97
57	7,244	0.471	17.92%	11.65	12475.73



a) Ward 44 (Bandaru) with least green cover



b) Ward 37 (Maroli) with maximum green cover



c) Ward 10 (Baikampady) with maximum per capita green space

According to the latest World Bank Records, per capita Carbon Dioxide (CO₂) emission in India is 1.7 tonnes. More the population, more will be the Carbon Emission and hence will need more number of trees to sequester the carbon emitted. Hence per capita green space is calculated to analyse the spatial distribution of trees and population.



58	6,378	0.64	11.30%	11.34	10174.52
59	7,717	0.72	24.44%	22.8	24083.07
60	8,542	2.44	31.73%	90.64	109922.44

DISCUSSION AND CONCLUSION

Currently the main Central Business District (CBD) region of Mangalore has less per capita green space. Central Market (41), Bandaru (44) have less than 10% green cover. Per capita green cover of these two wards are approximately 10.8 m²/inhabitant and 1.1 m²/inhabitant which is. Port (45), Cantonment (46) and Mangaladevi (56) and Bolar (58) have less than 12% green cover. These wards near port, are old part of the city where population density is high and city has grown in unplanned haphazard manner. Derebail (17) region is new developing part of the city with many emerging high rise apartments and housing colonies. This ward also has green cover less than 15% and green space/ inhabitant less than 15m². Baikampady (10) is a new industrial region which has very less population density. Currently this ward has approximately 26% green cover and since the region has very low density, green cover/ capita is 242.83m². When regions around industrial sector grow and more population migrate towards that region there can be pressure on green cover. This is what happened in new developed regions around Derebail. With the decrease in per capita green space, city also becomes less livable.

In 2005, Gujarat Urban Development Mission (GUDM) of the Urban Department and Forest department took initiative of Nagar Nandan Van Yojna. This programme helped to improve tree cover in the state. In 2009, Gujarat Urban Development Department emphasized on 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. Schools and educational institutions were also involved in such programmes. With such initiatives there was a drastic increase in Urban Green. Such initiatives can be taken up by Mangalore Urban Development Authority with community level participation. New evaluative programmes can be initiated among different wards with the fundamental criteria like per capita green space, green space to land ratio, green space canopy coverage ratio and funds can be allotted accordingly via different schemes.

For this, initial step could be to count and assess the present tree cover and the status of environment. This is necessary to estimate the diversity of trees in the city. This can be done with the help of Social Forestry Unit of Karnataka Forest Department. Tree census will create a baseline to monitor tree cover in different wards and will also help in assessing Carbon storage and also scope of Carbon sequestration in the Urban areas. Calculating the population and number of trees in each ward will indicate whether the region has sufficient green space for health and livability or if there is a need to increase the green cover of that region. Therefore, we can calculate number of trees needed to be planted to meet a minimum standard of 15 m² tree cover/inhabitant in city. It might be difficult to increase tree cover beyond a limit in some of the municipal corporation areas due to non-availability of the space. This gap can be compensated by increasing tree cover in sub-urban areas under Urban Development Authorities but it needs to be taken care that new trees planted should be near the ward boundary itself so that the purpose for which these trees are planted (supply of oxygen, carbon sequestration, etc.) is sufficed.

Mangalore city is growing at a very fast rate and an effective, planned and systematic management of the trees in the city is needed. If the growth of cities is not properly planned, this can lead to Urban Heat Islands with climatic changes and unlivable conditions. An approach towards “Urban tree management” should be stressed upon. City planners and designers need to be more sensitive towards ecological balance and sustainability. Trees are often considered as second thought after the development has already taken place rather than being incorporated as original design phase. Hence proper planning is needed for large scale development. Before the city expands further, a proper vision should be taken by administrative authorities for making the city green. This can be achieved by regulating land availability in the form of parks and gardens and forest patches and giving more emphasis on road side plantation. Urban forestry manages and protects forests and helps in planting new trees on barren lands with the purpose of helping in the environmental, social and urban development. Urban forestry department can be linked with Urban planning department such that Social Forestry and Urban forestry



can be integrated into Urban Planning. In Smart City Concept, Green cover of the city needs to be considered as an infrastructure of the city for sustaining human population and quality of life and funding for increasing green cover of the city can be allotted as infrastructure development to enhance the quality of life in city.

APPENDIX

For Calculating Carbon sequestration rate

1. There are two methods of carbon estimation in tree species: destructive method and non - destructive method. The latter one is approved by many researchers. For St Aloysius College campus study, non-destructive method for carbon estimation is employed. In this method we need not harvest the entire bio - volume and sacrifice the tree.
2. The girth of the tree is measured at the girth at breast height (GBH) 1.32 m above ground surface.
3. Tree diameter (D) is measured as $D = GBH \div 3.14$ (assuming the tree trunk to be cylindrical) Biomass in the above listed tree species is calculated by simply applying bio-statistics based allometric equations.
4. Above Ground Biomass (AGB) is estimated by multiplying the bio - volume to the green wood density (WD) of tree species. Tree bio - volume (Tbv) value is calculated by the value multiplying the diameter and height of tree species by a factor 0.4.

$$T_{bv} = 0.4 \times D^2 \times H \quad \dots\dots\dots (1)$$

$$AGB = WD \times T_{bv} \quad \dots\dots\dots (2)$$
5. Where H = Height (meter). Wood density is used from Global wood density database, The standard average density of 0.6 gm/ cc (600kg/cc) is applied wherever the density value is not available for tree species.
6. The Below Ground Biomass (BGB) is calculated by multiplying the above ground biomass (AGB) by a factor of 0.26 as the root to shoot ratio

$$BGB = AGB \times 0.26 \quad \dots\dots\dots (3)$$
7. Total Biomass (TB) is the sum of the above and below ground biomasses.

$$TB = AGB + BGB \quad \dots\dots\dots(4)$$
8. Carbon Estimation: Generally, for any plant species 50% of its biomass is considered as carbon (C) content in the tree

$$C = TB \div 2 \quad \dots\dots\dots (5)$$
9. Determination of the weight of carbon dioxide sequestered in the tree:
10. CO₂ is composed of 1 molecule of Carbon and 2 molecules of Oxygen. The atomic weight of Carbon is 12.001115. The atomic weight of Oxygen is 15.9994. The weight of CO₂ is C+2O = 43.999915. The ratio of CO₂ to C is 43.999915/12.001115 = 3.6663. Therefore, the weight of CO₂ sequestered in the tree is determined by multiplying the weight of carbon obtained in equation (5) by a factor of 3.6663 i.e.,

$$CS = C \times 3.6663 \quad \dots\dots\dots (6)$$
11. The carbon sequestration rate was calculated as 1% of the standing biomass each year.



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Ward	Name	Population	Area (sq.km)
Mangalore Ward No 01	Surathkal West	9,346	3.49
Mangalore Ward No 02	Surathkal East	7,109	6.22
Mangalore Ward No 03	Katipalla East	8,599	0.7
Mangalore Ward No 04	Katipalla Krishnapura	9,522	1.24
Mangalore Ward No 05	Katipalla North	9,935	0.89
Mangalore Ward No 06	Idya East	9,336	2.31
Mangalore Ward No 07	Idya West	8,046	1.93
Mangalore Ward No 08	Hosabettu	9,535	1.94
Mangalore Ward No 09	Kulai	10,649	4.13
Mangalore Ward No 10	Baikampady	7,503	7.07
Mangalore Ward No 11	Panambur	9,930	4.48
Mangalore Ward No 12	Panjimogaru	8,555	2.42
Mangalore Ward No 13	Kunjathbail North	8,615	1.3
Mangalore Ward No 14	Marakada	8,342	1.78
Mangalore Ward No 15	Kunjathbail South	7,137	2.75
Mangalore Ward No 16	Bangrakuluru	8,300	3.14
Mangalore Ward No 17	Derebail North	10,393	0.9
Mangalore Ward No 18	Kavoor	11,781	3.42
Mangalore Ward No 19	Pachchanadi	8,120	2.3
Mangalore Ward No 20	Tiruvail	9,146	3.41
Mangalore Ward No 21	Padavu West	8,354	1.4
Mangalore Ward No 22	Kadri (Padavu)	10,955	2.43
Mangalore Ward No 23	Derebail East	10,096	2.45
Mangalore Ward No 24	Derebail South	9,367	1.86
Mangalore Ward No 25	Derebail West	8,253	0.45
Mangalore Ward No 26	Derebail North East	9,023	0.43
Mangalore Ward No 27	Boluru	7,077	0.4
Mangalore Ward No 28	Mannagudde	6,741	0.58
Mangalore Ward No 29	Kambla	6,650	0.48
Mangalore Ward No 30	Kodialbail	6,380	0.5
Mangalore Ward No 31	Bejai	8,370	0.73
Mangalore Ward No 32	Kadri North	7,158	1.35
Mangalore Ward No 33	Kadri South	6,497	1.05
Mangalore Ward No 34	Shivabagh	6,396	0.62
Mangalore Ward No 35	Padavu Central	8,859	2.32
Mangalore Ward No 36	Padavu east	7,460	1.75
Mangalore Ward No 37	Maroli	7,797	1.82
Mangalore Ward No 38	Bendoor	7,322	0.78
Mangalore Ward No 39	Falnir	7,740	0.63
Mangalore Ward No 40	Court	6,917	0.59
Mangalore Ward No 41	Central Market	5,829	0.71
Mangalore Ward No 42	Dongarakeri	7,149	0.48
Mangalore Ward No 43	Kudroli	6,250	0.29
Mangalore Ward No 44	Bandaru	6,749	0.21
Mangalore Ward No 45	Port	7,449	0.5
Mangalore Ward No 46	Cantonment	6,908	0.64
Mangalore Ward No 47	Milagres	7,998	0.9
Mangalore Ward No 48	Velencia	8,509	1.17
Mangalore Ward No 49	Kankanadi	9,350	1.38
Mangalore Ward No 50	Alape South	7,026	1.13
Mangalore Ward No 51	Alape North	7,954	0.327
Mangalore Ward No 52	Kannuru	8,075	0.346
Mangalore Ward No 53	Bajal	8,602	1.91
Mangalore Ward No 54	Jappinamogaru	7,314	1.71



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Venue: V.S. Acharya Auditorium, Alva's Education Foundation, Sundari Ananda Alva Campus, Vidyagiri, Moodbidri, D.K. Dist., Karnataka, India – 574227

Mangalore Ward No 55	Attavara	8,398	1.09
Mangalore Ward No 56	Mangaladevi	8,216	0.34
Mangalore Ward No 57	Hoigebazar	7,244	0.47
Mangalore Ward No 58	Bolar	6,378	0.64
Mangalore Ward No 59	Jeppu	7,717	0.72
Mangalore Ward No 60	Bengre	8,542	2.44

Population as per 2011 census