BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL,

Principal Bench, New Delhi

Original Application No. 462/2018
(Earlier O.A. No. 11/2018 (SZ)
With
Original Application No. 76/2015 (SZ)

In the matter of: -

D. V. Girish — Applicant(s)

Versus

Union of India & Ors. — Respondent(s)

With

D. V. Girish — Applicant(s)

Versus

The Member Secretary National Tiger Conservation Authority, MoEF & Ors. — Respondent(s)

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2.	**Annexure-I:** A copy of Hon'ble NGT order dated 19.03.2020.	

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Date: 12.03.2021
Place: Delhi

Assessment of Environmental Carrying Capacity of Eco – sensitive Zone: Sanjay Gandhi National Park, Mumbai, Maharashtra

Submitted in the matter

O.A. No. 462/2018

D.V Girish Vs Union of India & Ors.

Central Pollution Control Board

March 2021

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Executive Summary

Eco-Sensitive Zones (ESZs) or Ecologically Fragile Areas (EFAs) are areas in India notified by the Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India around Protected Areas, National Parks and Wildlife Sanctuaries. The purpose of declaring ESZs is to create "shock absorbers" to the protected areas by regulating and managing the activities around such areas. These zones are indispensable for a nation as they preserve biologically and ecologically rich areas and potentially valuable and unique natural resources that would be difficult to replace once annihilated. The ecosystem is quite delicate around these areas and needs to be protected against human intervention. They are of immense importance to human society as they are ecologically and economically important, maintain ecological stability and preserve the rarity of the ecosystems they harbor.

Hon'ble NGT order dated 19th March 2020 in O.A No. 462/2018 directed that "*The CPCB may coordinate with the concerned authorities, including the State Administration, for undertaking carrying capacity assessment of at least one eco-sensitive area in the State, which may be thereafter replicated for all eco-sensitive area in next three months*".

Carrying capacity assessment is a tool to determine the growth limits that an area can accommodate without violating environmental capacity goals. CSIR-NEERI being an expert organization was engaged for a short term study to assess environmental carrying capacity (ECC) of Eco-sensitive zone – Sanjay Gandhi National Park, Mumbai using secondary data, remote sensing data, literature survey and selected ECC methodologies.

The findings reveals that environmental attributes such as available water resources, vegetation cover and land stress are within the permissible carrying capacity limits, however, other attributes such as mangrove cover, air quality (except SO_2) and surface temperature are deteriorating. The overall noise levels are within the limits except at the entrance gate. The utilization ratio of availablewater resources in SGNP is 59.87%, which is less than the reference value of 100%.

The total calculated footfall, in terms of tourists, shows that it is in a critical stage and has exceeded the maximum footfall possible and can affect the wildlife and its carrying capacity. The overall noise levels is within the acceptable limit except at SGNP entrance gate due to high traffic flows and other human activities, and it should be controlled through by suitable measures. The utilization ratio calculations for air pollutants except SO_2 are already beyond the safe limits and necessary air pollution control measures are required to be taken in and around the eco-sensitive zone of Sanjay Gandhi National Park.

The comparison of NDVI values indicates that the vegetation cover of SGNP has increased over the years, which is a good sign for the enhancement of its carrying capacity. The LULC classification area for SGNP from 1978-2020 shows a positive increase in forestland, is beneficial for wildlife and overall ecosystem. However, the Mangroves cover and water bodies areas, in the SGNP and buffer area (analyzed through remote sensing data) are decreasing year by year. Human settlements is continuously increasing including in buffer area threating environmental balance. LST maps of SGNP shows that the surface temperature has increased in 2020 (24-34ºC) as compared to 2000 (17.93 ºC). Preliminary analysis of SGNP indicates limited land stress which should be maintained for ecological balance. The values of AOD and indicate higher air pollution level due to anthropogenic activities, which is also confirmed by available ground data.

Based on the rapid assessment of CC done using the available data, it is recommended that,

1. Anthropogenic activities including construction within the premises of the SGNP should be limited as it is affecting the fragile ecosystem of the area and is putting pressure on other environmental attributes such as water, air and noise.
2. Assessment of noise carrying capacity needs a detailed analysis with biodiversity centric focus, given the severe impact of noise on fauna present in the area. A long term study is needed in this regards.
3. Suitable measures to mitigate the impacts of air and noise pollution in the area should deployed and an environment management plan be prepared to preserve the floral and faunal biodiversity.
4. The slope factors of the area shows a reduced stress on land which should be maintained by avoiding construction activities in the area.

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1.0 Introduction

Eco-Sensitive Zones (ESZs) or Ecologically Fragile Areas (EFAs) are areas in India notified by the Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India around Protected Areas, National Parks and Wildlife Sanctuaries. The purpose of declaring ESZs is to create "shock absorbers" to the protected areas by regulating and managing the activities around such areas. The ecosystem is quite delicate around these areas and needs to be protected against human intervention. They are of immense importance to human society as they are ecologically and economically important, maintain ecological stability and preserve the rarity of the ecosystems they harbor. In view of this, Hon'ble NGT vide its order dated 19th march, 2020 in O. A No. 462/2018 directed that "*The CPCB may coordinate with the concerned authorities, including the State Administration, for undertaking carrying capacity assessment of at least one eco-sensitive area in the State, which may be thereafter replicated for all eco-sensitive area in next three months*." CSIR-NEERI being an expert organization was engaged to conduct a short term study on "Assessment of Environmental carrying capacity of Eco-Sensitive Zone: Sanjay Gandhi National Park, Mumbai".

Among the four national parks within the state of Maharashtra, Sanjay Gandhi National Park (SGNP), which was previously known as Krishnagiri Upawan and later as Borivali National park, is an alluringly protected green area which is located around 25 km north of Mumbai city and 8 km from the shores of Arabian Sea [1]. It lies between 72^{0} 53' & 72^{0} 50' East longitude and 19^{0} 88' & 19^{0} 21' North latitude [1].Geographically, the southern boundary of the park is shaped by the Shore of Vihar Lake, the eastern by the townships of Bhandup, Mulund, and Thane, and the western by Goregaon, Malad, Kandivali, and Borivali suburbs of Mumbai. The northern boundary expands past Bassein creek and incorporates the Nagla forest block [1]. The park covers an area of 103.09 sq. km, out of which the recreational sector alone takes up 5.06 sq. km. SGNP is one of the foremost highly visited national parks within the country. The important tourist spots of SGNP include the Krishnagiri Upawan sector, which comprises the recreation zone and over 2000 years old Buddhist caves popularly known as Kanheri caves [1]. The major sources of water in the park are Tulsi and Vihar lakes. These man-made lakes having a combined catchment area of 25.72 sq. km are over 100 years old and are a source of drinking water supply to Mumbai city [1]. Along with these lakes, there are streams and water holes that act as water sources during the monsoon season [2]. The park shows varied terrain qualities from 30 m over sea level to nearly 500 m and exhibits coastal, dry and mixed deciduous and typical Western Ghats plateau habitats. With its seasonal cyclic changes, the SGNP habitat is fascinating at any time of the year. The mean annual temperature is 27^0C and over 2000 mm of rainfall is recorded in slightly over 100 days [2]. Due to its proximity to the coast, numerous watercourses, and hilly terrain, the flora too presents a very diverse picture, ranging from dry and moist deciduous to semi-evergreen, open scrub, and halophytes [1]. The studies also reveal that the park is very rich in fauna and has many endangered flora and fauna species. As per Wildlife Institute of India's Bio-geographical classification, SGNP falls in "The Western Ghats Bio-geographic Zone-5 and is considered an Eco-Sensitive Zone. From literature survey, it is known that many medium and large-scale chemical and engineering industries are located close to the park boundary, mainly at Malad, Goregaon, Dahisar, and Thane. Many human activities such as urbanization and encroachment, are hampering the ecological balance of resources in SGNP. Without a doubt, recent researches show that the capacity of the environment to maintain a specific level of movement may have been surpassed in a few zones, and thus, it has become essential to evaluate the carrying capacity of SGNP. In this report, the environmental attributes such as air, water, habitat, noise, land, flora, and fauna of SGNP are studied along with tourism activities prevailing there and are considered as indicators for the assessment of the Environmental Carrying Capacity (ECC) of SGNP.

1.1 Objectives of the Study

The main objective of this study is to perform the carrying capacity assessment of eco sensitive zone Sanjay Gandhi National Park, Mumbai, Maharashtra. The study is divided into two parts:

Part 1: Demarcation of the study area and collecting basic details from remote sensing and literature survey such as arid extent, geographical features, flora and fauna, and the tourist activities.

Part 2: Carrying capacity assessment with selected methodologies by considering air, water, habitat, biodiversity, land, noise, and tourism as the crucial elements affecting SGNP by using fuzzy comprehensive evaluation method based on secondary data available.

1.2 Stages of the study

Demarcation of the study area: The study area is analyzed in detail to ascertain the geographical features, arid extent, and the watersheds available. Remote sensing tools and techniques with the support from literature are used to finalize the study area.

Selection of suitable methodologies: The carrying capacity assessment of SGNP is done by sectioning the environment into several components, which include land, air, water, habitat, biodiversity noise, and tourism. Suitable methodologies are selected by exploring recent research articles in the field of environmental and ecological carrying capacity assessment

Compilation of details: The basic details for the study area based on selected methodologies are collected and analyzed for carrying capacity assessment.

Preparation of maps: Required maps for the study area to aid the carrying capacity assessment are prepared with ArcGIS/QGIS platforms along with Google Earth Pro.

Carrying capacity assessment: With the help of selected methodologies, secondary literature and the data therein and maps, carrying capacity assessment is conducted.

1.3 Details of the study area

Sanjay Gandhi National Park is located in Mumbai city, Maharashtra. The park's boundaries consist of North – Nagla Forest Block, South – Vihar lake, West – Goregaon, Malad, Kandivali & Borivali suburbs, East – Township of Bhandup, Mulund & Thane. The total area of the park is about 103.9 sq.km [2], of which 87 sq. km comes under Mumbai city, as indicated in the literature. The coordinates of the park are 19°24´N 72°68´E. Figure 1.1 shows the location of SGNP, Mumbai-Maharashtra.

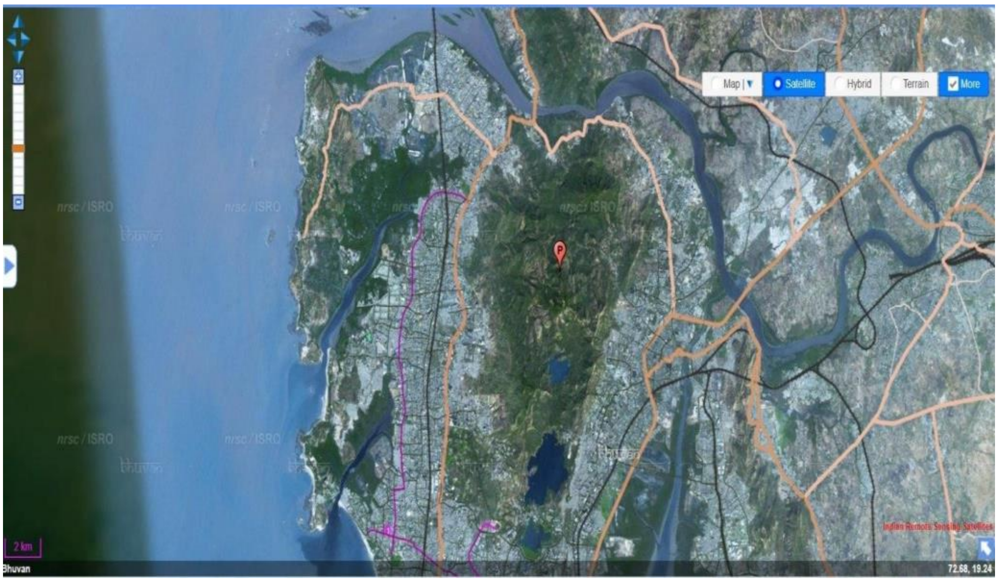


Fig. 1.1: Location of the study area-SGNP, Mumbai-Maharashtra (Bhuvan Map)

2.0 Methodologies for Assessment of Environmental Carrying Capacity

Environmental Carrying Capacity (ECC), is important to ascertain the limits of development within the sustainable framework. This also becomes important with reference to UN sustainable development goals 2030; Goal 15: "Protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". The estimations of carrying capacity for the ecosystem identified can be expressed as the relationship between natural resources, environment and human economy to achieve sustainable and overall development. This concept along with maintaining resources includes socio-economic growth of the society. Therefore, estimation of ECC becomes essential for any ecosystem so that inclusive growth can be ascertained. These estimations help in deriving the supporting and pressure factors for the ecosystem. The following flowchart depicts the methodology followed for estimating ECC of the study area:

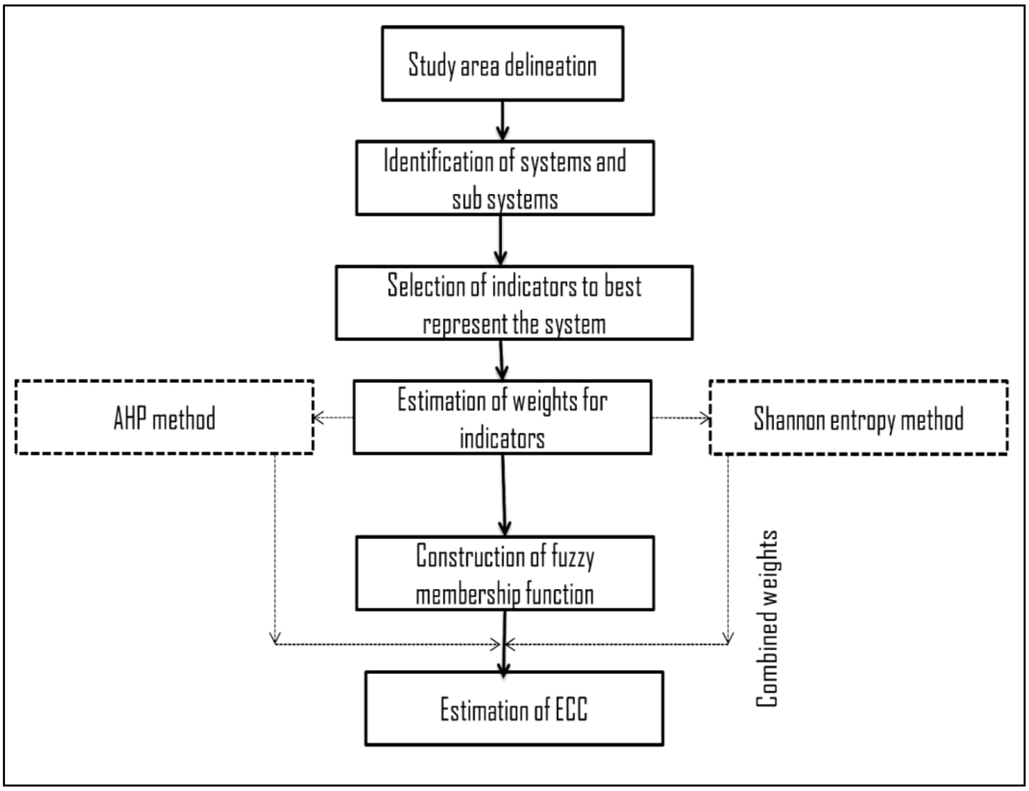


Fig. 2.1: Flowchart showing methodology for estimating ECC

The above method is detailed and needs varied data points to complete the assessment. Some of the data points are described in the table below. The estimation of ECC can be done by a categorical selection of processes for ecological resilience and quantification of ecological pressure. This study uses 12 factors that act as an indicator to subsystem to include resilience and pressure of the ecological system. The factors to quantify resilience are slope (R1), Land Use (R2), Land Stress Index (R3), Habitat Quality Index (R4), Water Network Denseness Index (R5), Vegetation Cover (R6), Annual Total Rainfall (R7), Annual Total Temperature (R8), Aerosol Optical Depth (P1), $PM_{2.5}$ (P2), Temperature (P3), Heat Intensity (P4). The selected indicators are those which can capture the interactions existing between subsystems and processes. These 12 indicators are believed to have an impact on the ECC of the study area. These selected indicators can be distributed spatially and temporally for estimation of ECC. [6]

Table 2.1: Select ECC Parameters

Criterion Layers	**Sub - Criterion Layers**	**Factor Layers**
Ecological Resilience (A_1)	Soil Erosion (B_1)	Slope (U_1)
		Land Use (U_2)
		Land Stress Index (LSI) (U_3)
	Land Cover (B_2)	Habitat Quality Index (HQI) (U_4)
		Water Network Denseness Index (WNDI) (U_5)
		Vegetation Cover (VC) (U_6)
	Climatic Factors (B_3)	Annual Total Rainfall (U_7)
		Annual Total Temperature (U_8)
Ecological Pressure (A_2)	Air pollution (B_4)	AOD (U_9)
		$PM_{2.5}$ (U_{10})
	Urban Heat Island (B_5)	Temperature (U_{11})
		Heat Intensity (U_{12})

In order to conduct a detailed assessment as above, the study area is to be defined critically. Hence, a buffer zone is chosen around the SGNP. Buffer Zone is usually an area assumed to fortify the preservation of protected area. For the carrying capacity assessment study, we have selected a radius of 5 km as buffer zone around SGNP to regulate certain activities around national parks and wildlife sanctuaries and to minimize negative impact on the delicate environment. Eco Sensitive Zones are shaped to serve as "shock absorber" for protected areas. In this case, the buffer zone is used to map the environmental attributes in and around the SGNP.

While assessment of ECC based on above methods is a tedious and complex process, a simplified approach can be used to get indicative results. This simplified process is applied for assessment of water, noise, air and tourism carrying capacity of SGNP. The Analytic Hierarchy Process (AHP), modelling and Fuzzy logic based complex processes can be explored once simplified approach is applied. The detailed methods for each of above environmental attributes are described in subsequent sections.

2.1 Water Environment Carrying Capacity (WECC)

Water plays a vital role in human survival and regional socio- economic development. Water resources are valuable natural resources, such as surface water, groundwater and frozen water. Employment based of water includes agricultural, industrial, household, recreational and environmental activities. With rapid population growth and economic development, conflict between environment and human has increased. Therefore, the study of WECC is the foundation of sustainable development and water security strategy.

The SGNP consists of lakes, major & minor streams, waterholes, and wells. Out of these, the two lakes of SGNP - Tulsi and Vihar are over a 100 years old and are the primary source of drinking water supply to Mumbai city. Since it is feeding water to one of India's most populated city and wildlife population, its water resource carrying capacity assessment is important.

Water Environment Carrying Capacity (WECC) Estimation

To evaluate the WECC of SGNP, it is essential to understand and study the available water resources present in the SGNP. The characteristics and data of available water resources such as its catchment area, surface area, maximum & minimum depth, surface elevation and water volume are considered for study [2]. The available water resources can be defined as the maximum exploitable water resources without negative impacts on the environment. It can be characterized as the total of locally available surface water, groundwater, trans-boundary water, and reclaimed water. The amount of available water resources was calculated based on average annual meteorological & water supply engineering conditions and supplying quota

allocated by government [7]. It is estimated using the following equation.

$$\mathbf{E_{ws}\,(m^3) = W_s + W_g + W_t + W_{uc}} \qquad [7]$$

Where, E_{ws} = Amount of available water resources W_s = Amount of available surface water W_g = Amount of available groundwater

W_t = Amount of transfer water from cross-boundary regions

W_{uc} = Reclaimed water sources including wastewater recycling

Data related to the amount of water taken for consumption from the available water resources of SGNP are collected from respective organizations and the total water consumption in a year is calculated.

The Utilization Ratio (UR) was connected to explore the degree to which WECC was utilized by the economy. The UR of available water resources can be estimated by using the equation given below [7].

UR Available Water Resources = Amount of Water Consumed / Total Available Water Resources

If UR > 100%, the resources are overused, or the environment is overloaded [7].

2.2 Air Environment Carrying Capacity (AECC)

Air is a critical resource for humans, plants, animals, and all other living organisms within a natural habitat. Many air pollutants, such as tropospheric O_3 and NOx, affect the metabolic function of the leaves and interfere with net carbon fixation by the plant canopy. Air pollution can affect wildlife indirectly by changing plant communities. It can harm wildlife in two main ways,

- Affecting the quality of the environment or habitat in which they live.
- Affecting the availability and quality of the food supply.

Air Environment Carrying Capacity (AECC) Estimation

For the assessment of AECC of SGNP, details about polluting sources in the vicinity and within the park were identified and quantified. The data considered include air pollution sources, type of air pollutant, and the baseline air quality of SGNP [2].

The baseline air quality data of SGNP, which includes the amount of SO_2, NO_2, SPM, and RSPM emitted, is compared with NAAQS values for sensitive areas, and the Utilization Ratio is estimated for each air pollutant.

Utilization Ration (UR) = Amount of pollutant load/ECC

If UR > 100%, the resources are overused, or the environment is overloaded.

2.3 Tourism Carbon Carrying Capacity (TCC)

Tourism is one of the fastest growing sectors globally. Tourism produces 5 percent of the world's carbon emissions, significantly impacting global warming [3]. Moreover, tourism can cause significant disturbances to animals in their natural habitats. As wildlife tourism in an area increases, more people interact with wildlife. Further, humans leave trash and other substances which adversely impact, the habitat.

Calculated TCC value for SGNP becomes important in view of the fact that it is a national park within metropolis limit and is one of the world's most visited parks.

Tourism Carbon Carrying Capacity (TCC) Estimation

For the assessment of TCC of SGNP tourism, details such as tourist spots inside the park premises, tourist inflow rates, etc. are collected [2] and carbon carrying capacity which refers to amount of fixed CO_2 absorbed by vegetation in an area every year is used for calculation. [3]

The land-use study of SGNP is conducted and details include land use pattern, area of forest, etc.

The TCC is calculated by using the following equation.

$CC = S \times C_{NEP} \times (44 \div 12)$ [3]

$TCC = CC \times r$ [3]

Where, CC = Region's carbon carrying capacity, S = Area of forest,

C_{NEP} = Amount of carbon absorbed by vegetation in one year, TCC = Tourism carbon carrying capacity,

r = Tourism carbon carrying capacity coefficient, which is the ratio of gross regional tourism revenue to Gross Regional Product (GDP)

2.4 Noise Carrying Capacity (NCC)

Sound, just like the availability of nesting material or food sources, plays an important role in the ecosystem. Activities such as finding desirable habitat and mates, avoiding predators, protecting the young, and establishing territories are all dependent on the acoustical environment.

Sound is what we hear, but noise is the unwanted sound. In general, a growing number of studies indicate that animals, like humans, are stressed by noisy environments. Noise pollution makes it difficult for them to accomplish their activities, which affects their survival. Studies have shown that loud noises cause caterpillars' hearts to beat faster and bluebirds to have fewer chicks. Hence, a detailed study is required to be conducted to determine the sound pressure levels generated due to visitor noises, vehicles, due to any industries within and near SGNP, to strengthen the existing baseline data for future long term monitoring of the impacts of sound on wildlife since SGNP.

Noise Carrying Capacity (NCC) Estimation

Accordingly, it is necessary to figure out the visitor attraction sites within the SGNP where there is maximum visitor footfall. Thereafter, it is essential to record the sound levels in different seasons with (impact) and without (control) the presence of visitors in these specific zones [5].

Determination of NCC involves measuring the sound levels existing in high visitor usage sites through a control-impact design check whether the ambient noise level (Leq in dB) [5] remains within the prescribed noise level standard limits as per regulations for Silence Zone. The above factors of Noise, Air, Water and Tourism are critical for carrying capacity using simplified approaches as indicated. The detailed assessment of ECC needs assessment of various factors as described in Table 2.1 of ECC parameters. The assessment method for NDVI, LST, DEM, LSI, AOD, NDWI and HQI is detailed below.

2.5 Normalized Difference Vegetation Index (NDVI)

Vegetation cover has immense importance in wildlife because it releases oxygen and sequesters carbon, it protects soil from degradation and convert solar energy into biomass and forms the base of all food chains. For SGNP, with its rich green canopy and existing within a metropolis, it is essential to monitor any changes in its vegetation cover due to human activities. For this purpose, NDVI maps of SGNP for various years are prepared and are used to study any decrease in its vegetative cover by comparing the maps.

Normalized difference vegetative index (NDVI) is a simple graphical indicator used to analyze remote sensing measurements, often from a space platform assessing whether or not the observed target contains live green vegetation. NDVI is used to quantify vegetation greenness and is useful in understanding vegetation density and assessing changes in plant health. NDVI is calculated as a ratio between the RED (R) and NEAR INFRARED (NIR) values. For various studies, satellite images such as Landsat 3, 5, 8 data can be downloaded from USGS Earth Explorer.

After downloading the satellite image raw data, atmospheric correction and pre-processing are done through QGIS software. ArcGIS 10.6.1 platform is used to calculate the Normalized difference vegetation index based on the following equation.

$$NDVI = \frac{\mathrm{NIR-RED}}{\mathrm{NIR-RED}}$$

Maps are thus prepared for the years 1978, 1987, 2000 & 2020, and the total Vegetative and Non-Vegetative area of SGNP is calculated and compared.

2.6 Land Surface Temperature (LST)

Land surface temperature is another critical variable within the earth's climate system. It describes processes such as the exchange of energy and water between the land surface and the atmosphere, and influences the rate & timing of plant growth. Land surface temperature is influenced by many parameters such as solar incident radiation, angle of incidence of solar radiation, surface properties such as surface roughness, moisture content, extent of vegetation and air temperature. LST is also affected by land use/land cover changes. By preparing LST maps of SGNP and comparing them we would get an idea about the increase in surface temperature pronounced by any change in land use/land cover.

The Land Surface Temperature can be estimated or calculated using the Landsat 5, 8 thermal bands. It requires applying a set of equations through a raster image calculator in Arc Map, ArcGIS10.6.1 and QGIS. The first step is to download a Landsat 5, 8 images from a particular location, unzip it, and check certain information needed (within the metadata) to execute this procedure and to create Land Surface Temperature (LST) map using the Landsat 8 bands. In particular, band 10 is used as the thermal band, and bands 4 and 5 to calculate the Normal Difference Vegetation Index (NVDI).

To calculate the LST, the following USGS formulas are used,

- Calculation of TOA (Top of Atmospheric) spectral radiance.

TOA (L) = ML * Qcal + AL

where: ML = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number). MTL Radiance Mult Band Landsat 8 Meta datos

Qcal = corresponds to band 10.

AL = Band-specific additive rescaling factor from the metadata

(RADIANCE_ADD_BAND_x, where x is the band number).

MTL Radiance Add Band Landsat 8 Meta datos

TOA = 0.0003342 * "Band 10" + 0.1

Therefore, the equation must be solved using the Raster Calculator tool in ArcMap.

- TOA to Brightness Temperature conversion

BT = (K2 / (ln (K1 / L) + 1)) − 273.15

where: K1 = Band-specific thermal conversion constant from the metadata

K1_CONSTANT_BAND_x, where x is the thermal band number

K2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number).

L = TOA

Therefore, to obtain the results in Celsius, the radiant temperature is adjusted by adding the absolute zero (approx. -273.15°C).

The equation for TOA to Brightness Temperature by Landsat 8 is as follows

BT = (1321.0789 / Ln ((774.8853 / "%TOA%") + 1)) – 273.15

- Calculate the NDVI

NDVI = (Band 5 – Band 4) / (Band 5 + Band 4)

Note that the calculation of the NDVI is important because, subsequently, the proportion of vegetation (Pv), which is highly related to the NDVI, and emissivity (ε), which is related to the Pv, must be calculated.

NDVI = (Band 5 – Band 4) / (Band 5 + Band 4)

- Calculate the proportion of vegetation Pv

Pv = Square ((NDVI – NDVImin) / (NDVImax – NDVImin)

- Calculate Emissivity ε

  ε = 0.004 * Pv + 0.986

  Apply the formula in the raster calculator, and the value of 0.986 corresponds to a correction value of the equation.

- Calculate the Land Surface Temperature

  LST = (BT / (1 + (0.00115 * BT / 1.4388) * Ln(ε)))

Finally, apply the LST equation to obtain the surface temperature map. As a result of the process developed, a map of the Land Surface Temperature will be created and, it should be noted that it is not equal to the air temperature.

2.7 Digital Elevation Model (DEM)

The most common digital data of the shape of the earth's surface is cell-based digital elevation models (DEM). This data is used to quantify the characteristics of the land surface. It is mainly used to determine terrain attributes such as elevation at any point, slope and aspect. Dem maps of SGNP are very essential to perform carrying capacity assessment since it gives immense data for the assessment process. SRTM DEM data downloaded from USGS Earth Explorer and processed in ARCGIS 10.6.1 are used for making slope map of SGNP with 5 km buffer zone area.

The consideration of slope of the land is important to reduce construction costs, minimize risks from natural hazards such as flooding and landslides, and to minimise the impacts of proposed development on natural resources such as soils, vegetation and water system. Hence it is very important to understand the slope of a region and a map indicating the topography of an area along with an analysis of topographic features. Slope Maps of SGNP created from DEM data and processed in ARCGIS Software are used to compare and study its effects.

2.8 Land Use Land Cover Map (LULC)

Land- use and land cover (LULC) maps are used as powerful tools for tackling environmental problems, facilitating planning activities, and managing natural resources. It also refers to anthropogenic activities and uses being carried out on land. By comparing LULC maps of various years, the total area of a region utilised for development activities can be evaluated, and the same procedure is used for SGNP and for carrying capacity assessment. It has also been used for habitat quality index, land stress index and, water denseness index studies of SGNP.

ArcGIS 10.6.1 software platform is used for LULC map creation, and Supervised classification is done for LULC classification of SGNP with 5 km buffer zone area. Landsat 3, 5, 8 OLI data are used to calculate LULC in SGNP and From LULC classification areas are measured such as Forest, Vegetation, Settlements, Barren lands, Waterbodies, Agriculture & Mangroves of the Sanjay Gandhi National Park Area, Mumbai with 5 km buffer zone.

2.9 Normalized Difference Water Index (NDWI)

The NDWI is used to monitor changes related to water content in water bodies. It is also used to differentiate water from the dry land and is most suitable for water body mapping. Water bodies have low radiation and strong absorbability in the visible infrared wavelength range. It is also a remote sensing derived index estimating the leaf water content at the canopy level. During drought events, vegetation canopy can be affected by water stress, which can significantly impact plant development in general and can cause crop failure or lower crop production in agricultural areas.

Landsat 8 data is downloaded from USGS Earth Explorer. After downloading satellite image raw data, atmospheric correction and pre-processing is done through QGIS software. NDVI is calculated as a ratio between the NEAR INFRARED (NIR) and SHORT-WAVE INFRARED (SWIR) values.

$$NDWI = (NIR - SWIR) / (NIR + SWIR)$$

2.10 Land Stress Index (LSI)

The LSI is the degree of stress on the land quality in the evaluation area and is expressed by the area of the stress type, such as soil erosion, land desertification and land development, per unit area in the evaluation area.

For SGNP, land stress index map is created through Soil Loss Equation processing - Rainfall (R), Soil (K), DEM (Process – Slope – LS), LULC (C), and Land Management (P). Therefore, the Universal Soil Loss Equation, (A) = R*K*L*S*C*P is used.

Throughout the algorithm is processed in Map Algebra Tool and Land Stress Index Map of SGNP is created by ArcGIS 10.6.1 Software.

The formula for LSI is as follows:

LSI = A_{ero} * (0.4 * severe erosion area + 0.2 * mod erosion area + 0.2 * construction land area + 0.2 * other land stress)/area

A_{ero} = Normalization coefficient of LSI, with reference value of 236.0435677948.

2.11 Habitat Quality Index (HQI)

The HQI is mainly used to evaluate the suitability of the habitat quality of the main protected objects in nature reserves [9,10].

For SGNP Habitat Quality Index map is created by processing the following data - DEM (Process – Slope – LS), LULC (C), and Land Management (P).

Throughout, the algorithm is processed in Map Algebra Tool and Habitat Quality Index Map of SGNP is created by ArcGIS 10.6.1 software.

The formula for HQI is as follows:

HQI = A_{bio} * (0.35*forest + 0.21 * grass+0.28 * water +0.11 * agricultural land + 0.04 * construction land + 0.01 * unused land)/area

A_{bio} = Normalization coefficient of HQI, and the reference value is 511.2642131067.

2.12 Aerosol Optical Dispersion and $PM_{2.5}$

Aerosol Optical Depth is a measure of the extinction of the solar beam by dust and haze. In other words, particles in the atmosphere (dust, smoke, pollution) block sunlight by absorbing or scattering light. The value depends mainly upon meteorological conditions and anthropogenic activities in a region. Higher values of AOD denotes poor meteorological conditions with high anthropogenic activities. Likewise, by comparing $PM_{2.5}$ values of a region with NAAQS, a clear picture of air pollution existing in a region can be understood.

For this purpose, due to the data gapping in MODIS DT-AQUA, AODMODIS derived from DT-TERRA reflection with a spatial resolution of 3 km at 0.55 μm is used to characterize the spatial variation of aerosol optical depth and $PM_{2.5}$ over our study region. The study area is extracted using ArcGIS tools. In this, each dataset is converted to a point shape file using Arc tools for spatial interpolation. Generated maps are used for analysing spatial distribution patterns of aerosol and $PM_{2.5}$ [8].

Once all above environmental attributes are evaluated, it is possible to use more complex methods including Fuzzy and/or Analytical Heriarchy Process and/or Shanon Entropy Method for evaluation of ECC. The first step towards these processes include selection of ecological system, assessment of environmental attributes, application of weights, use of one of the above techniques for assessment of ECC.

2.13 Selection of ecological system

The selection of ecological system is important so that supportive and pressure state variables can be identified. Identifying the system leads to a comprehensive evaluation of carrying capacity, one by estimation of resource carrying capacity and the other is environmental carrying capacity, which, when combined, makes up the ecological carrying capacity. In this study, ecological resilience and ecological pressure subsystems were identified, which were represented through soil erosion, land cover, climatic factors and air pollution, urban heat island, respectively. These systems and variables are dynamic and ever changing, and hence the ECC of the region is dynamic, variable and continuously changing depending upon the status of natural resources and the environment. Once selected, the system needs to be represented by indicators that can best represent the system and can capture the existing interactions among different subsystems.

2.14 A Fuzzy Comprehensive Evaluation method

A fuzzy based model for ECC estimation helps in reducing the subjective effect of AHP and the objective effect of the Shannon Entropy method. In this method, the selected indicators are used for combined weights from AHP and Entropy method along with classes of ratings domain so as to evaluate the results of ECC. A finite group for rating domain can be selected such as V =[V_1, V_2, V_3, V_4, V_5] where V_1 is a very low grade, V_2 is a low grade, V_3 is a moderate grade, V_4 is a high grade, V_5 is a very high grade. The membership function based on the rating domain is selected to describe the degree of evaluation factors for the ECC. Depending upon the study area, suitable distribution can be used based on existing structural membership function [6]. This is represented by the following equation.

$$ECC = [W_1, W_2, \ldots \ldots W_n](\begin{matrix} u_1V_1 & \ldots & u_1V_n \\ u_mV_1 & \ldots & u_mV_v \end{matrix})$$

Where W is combined weight and uV matrix to be calculated as per the membership function.

Once the matrix is constructed, the ECC based on ecological pressure and ecological resilience is evaluated to estimate differential influences of indicators selected to best represent these two subsystems.

The estimation of ECC after selection of system and subsystem requires a comprehensive index so that variables with different scales can be used collectively to estimate ECC. The index calculation for factors and finally leading to estimation of ECC requires unified and comprehensive weight assigning procedure so that various scales and spatial variability is ascertained while estimating ECC. The ECC estimation has been done by different methods which include principal component analysis, analytical hierarchy process, fuzzy evaluation, ecological footprint model, comprehensive index, Shannon entropy, grey relationship model etc. and every method has its own advantage and disadvantage. Therefore, this study will use intersection of methods to reduce subjective and objective biases. This study proposes to develop a fuzzy based evaluation model on the AHP-entropy combined weight method using the influencing processes with 12 indicators identified to best represent those processes.

The combined weight for AHP-entropy method can be calculated as

$$W_i = \propto w_i + (1 - \propto) w_i'$$

To achieve the smallest sum of squared deviations of w, w′ and W, the function can be established as

$$\min W = \sum_{i=1}^{n} [\,(W_i - w_i)^2 + (W_i - w'_i)^2]$$

Once the combined weights are evaluated the ECC for the study area can be calculated as follows

$$ECC = \sum_{j=1}^{m} W_i Y_j$$

2.15 AHP Based Estimation Selection of Indicators

Remote Sensing (RS) and geographic information system (GIS) are emerging tools in analysis of carrying capacity. Environmental parameters such as aerosol optical depth

(AOD) which can be considered as a proxy for $PM_{2.5}$ is used as an indicator. Kriging techniques is used to interpolate values when AOD values are missing

The normalized difference vegetation index (NDVI) is used as an indicator and obtained from satellite data and the data is pre-processed similar to AOD.

NDVI data is derived from RS imagery to represent vegetation coverage and biological capacity. Soil brightness index (SBI) and soil wetness index (SWI) to represent soil conditions, which can indirectly reflect vegetation coverage and soil moisture. NDVI and SWI is derived using the following equations:

$$NDVI = (P_{NIR} - P_{red}) / (P_{NIR} - P_{red})$$

SBI = 0.31B2 + 0.28B3 + 0.47B4 + 0.56B5 + 0.51B6 + 0.19B7

SWI = 0.15B2 + 0.20B3 + 0.33B4 + 0.34B3 − 0.71B6 − 0.46B7

Here, B represents the Operational Land Imager (OLI) Band number. PNIR and Pred are spectral reflect values of near infrared OLI B5 (0.845-0.885 μm) and red OLI B4 (0.63-0.68 μm).

Similarly weighing for other indicators can also be done.

The indicators are averaged to yearly values and the carrying capacity are evaluated tentatively for the past 15 years (2006-2020) subject to data availability.

Scaling of Indicators

Since the indicators are of different units and dimensions, they are first standardized as per following formulas:

For positive indicators:

$$x'_{i,j} = \frac{(x_{i.j} - x_{jmin})}{(x_{jmax} - x_{jmin})}$$

For negative indicators:

$$x'_{i,j} = \frac{(x_{jmax} - x_{i,j})}{(x_{jmax} - x_{jmin})}$$

Where x’i,j are the normalized indicator values, x_{jmax} and x_{jmin} are the maximum and minimum values of the jth indicators and $x_{i,j}$ is the i_{th} year value of the j_{th} indicator.

Weight determination and CC evaluation

There are two popular methods for weight determination

1. Analytic Hierarchy Process (AHP)- AHP is a method or theory that involves pairwise comparisons for determining the weight of each index. Establishment of pairwise comparison matrices in AHP depends on expert judgment. However, the AHP method is subjective and the weights may vary based on the experts.
2. To avoid any subjective influences, an objective method of calculating weights is as follows:

$$E(j) = \frac{1}{m}\sum_{i=1}^{m} x'_{i,j}$$

$$\sigma(j) = \sqrt{\frac{1}{m}\sum_{i=1}^{m}\left(x'_{i,j} - E(j)\right)^2}$$

$$\omega_j = \sigma(j) / \sum_{j=1}^{n} \sigma(j)$$

Where, E(j) is the mean of the j^{th} indicator, σ (j) is the standard deviation of the j^{th} indicator, and ω_j is the weight of the j^{th} indicator.

Finally, the carrying capacity of the i^{th} year is evaluated by,

$$CC_i = \sum_{j=1}^{n} x'_{i,j}\,\omega_j$$

A higher CC value indicates a higher carrying capacity. In addition, statistically significant effects of individual indicators on carrying capacity and their correlation and contribution to the final carrying capacity are explored. A 15-year analysis gives an indication of long-term changes and trends in the indicators and the CC of the region, and whether the CC of the ecological park has been improving or diminishing with increased urbanization and development of the surrounding region.

3.0 Assessment of Environmental Carrying Capacity and Environmental Attributes

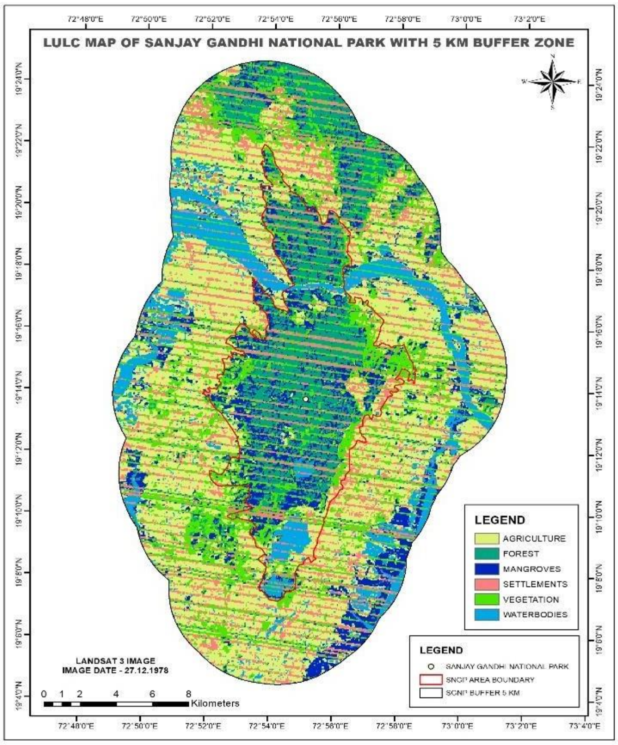
The calculations of the different parameters of the Ecological Carrying Capacity are done with the estimation methods discussed in previous section and by considering the data from the Environmental Management Plan for SGNP 2000.

3.1 Calculation of Tourism Carbon Carrying Capacity (TCC)

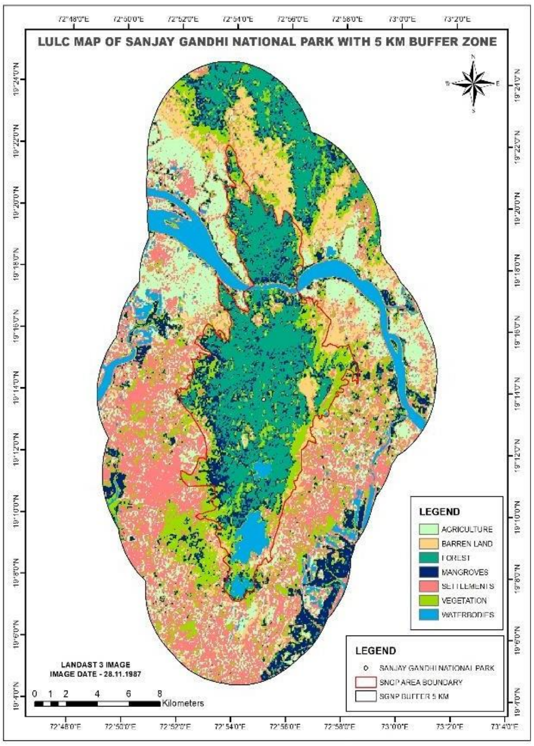
For the calculation of Tourism Carbon Carrying Capacity, area is considered from the LULC maps created by ArcGIS and tourist inflow details are taken from Environmental Management Plan for SGNP 2000. TCC is estimated by using the CO_2 sequestration method and the calculations are as follows,

Land Use Land Cover (LULC) of SGNP with Buffer Zone

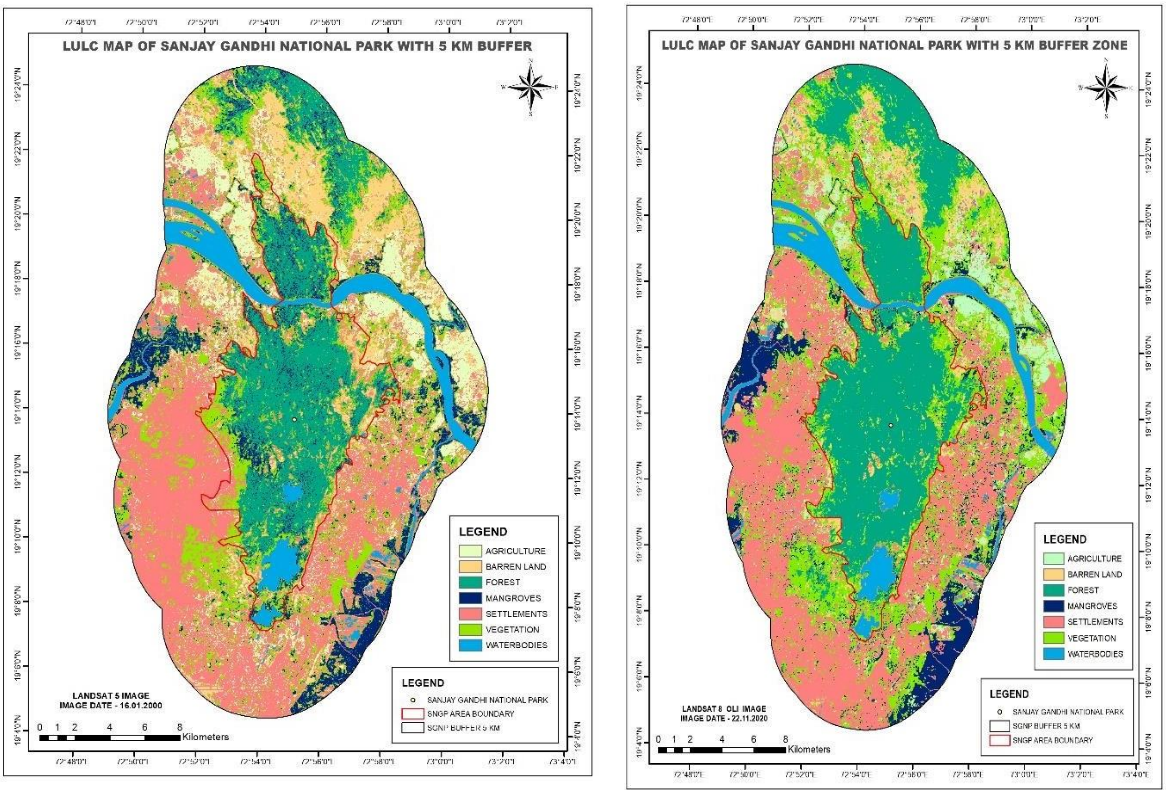
The maps of LULC of the study area with buffer zone for the different years are shown below:



(a)



(b)



(c) (d)

Fig. 3.1(A) Land Use Land Cover (LULC) Map of SGNP with Buffer Zone: (a) 1978, (b) 1987, (c) 2000, (d) 2020

The details of land use land cover for the study area with buffer Zone are as follows,

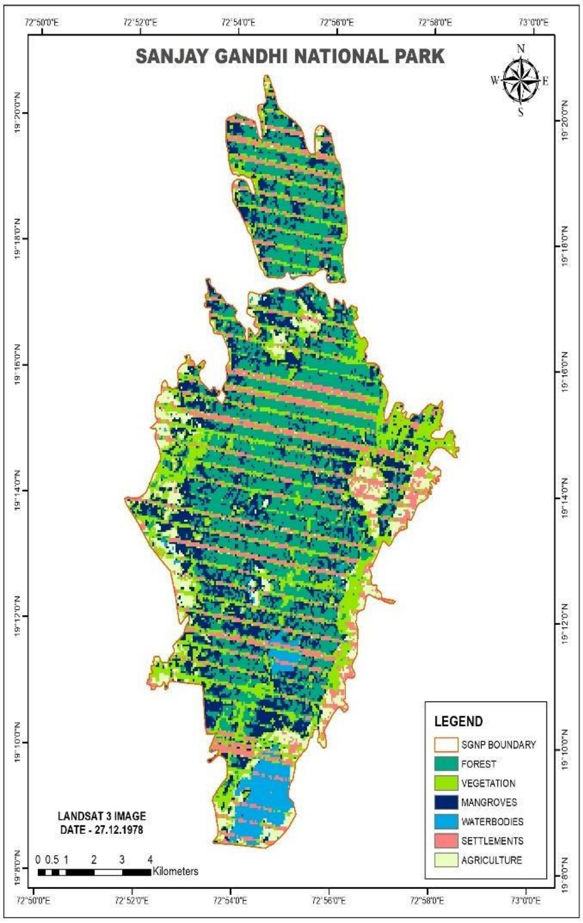
Table 3.1(A): Details of LULC Map with Buffer

Category	**Year-1978**	**Year-1987**	**Year-2000**	**Year-2020**
	Area (Sq.km)	**Area (Sq.km)**	**Area (Sq.km)**	**Area (Sq.km)**
Forest	67.7	88.70	96.93	127.23 ↑
Vegetation	110.59	92.30	92.77	124.57 ↑
Mangroves	58.78	59.11	43.50	38.52 ↓
Water bodies	48.73	36.36	31.76	30.18 ↓
Settlements	83.60	136.83	180.96	163.87 ↑
Agriculture	181.76	89.13	60.78	32.91 ↓
Barren land	--	48.74	44.49	33.89 -
Total Area	551.19	551.19	551.21	551.21

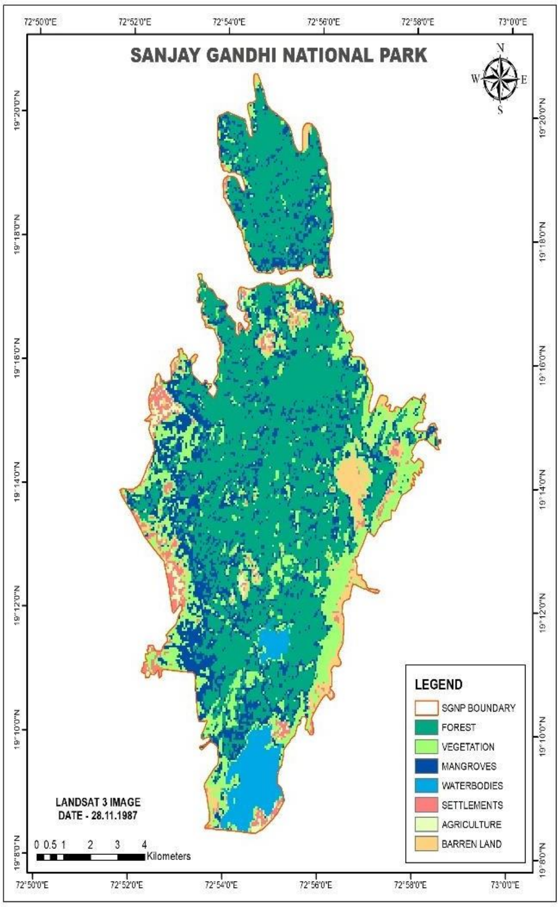
The LULC classification area for SGNP from 1978-2020 shows a positive increase of forest land which is beneficial for the wildlife ecosystem. Mangroves and water body areas are however decreasing year by year and indicates a threat to the balance of the environment. Human settlements are also increasing year by year till the year 2000, while showing reduction after that. Though, remote sensing needs to be ground verified to understand the actual status of human settlements in the SGNP. In general terms, encroachments in the ecologically sensitive area needs to be prevented in order to maintain the balance of fragile ecosystem.

Land Use Land Cover (LULC) of SGNP

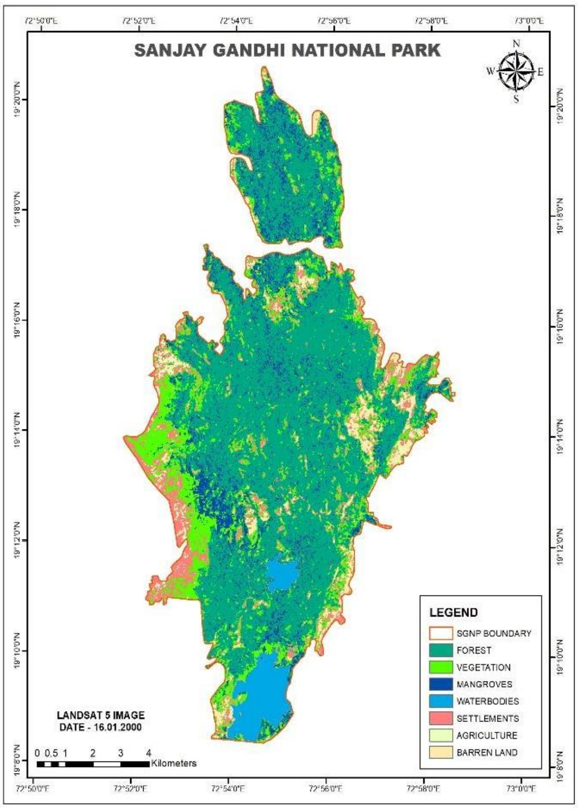
The maps of LULC of the study area for the different years are shown below:



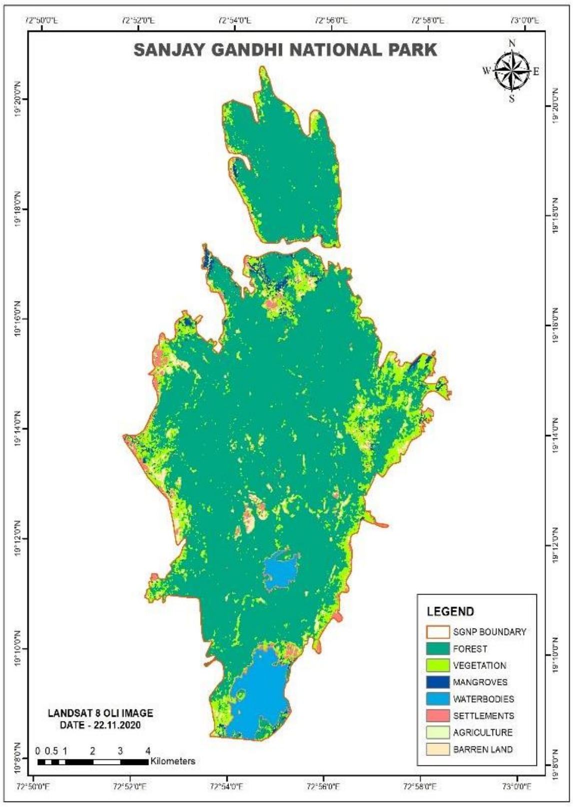
(a)



(b)



(c)



(d)

Fig. 3.1(B) Land Use Land Cover (LULC) Map of SGNP: (a) 1978, (b) 1987, (c) 2000, (d) 2020

The details of land use land cover for the study area are as follows:

Table 3.1(B): Details of LULC Map of SGNP

Category	**Year-1978**	**Year-1987**	**Year-2000**	**Year-2020**
	Area (Sq.km)	**Area (Sq.km)**	**Area (Sq.km)**	**Area (Sq.km)**
Forest	40.16	59.84	68.35	90.31 ↑
Vegetation	26.93	22.09	18.30	15.68 ↓
Mangroves	24.67	22.47	11.78	1.89 ↓
Water bodies	4.23	5.24	5.17	5.24 ↑
Settlements	--	3.98	9.99	2.89 -
Agriculture	9.28	1.64	1.71	0.67 ↓
Barren land	--	4.39	4.34	2.96 -
Error in Image	14.36			-
Total Area	119.67	119.67	119.66	119.66

Table 3.2(A): Baseline Data of Water

Name	Area (Hectare)			
	Year - 1978	**Year - 1987**	**Year – 2000**	**Year - 2020**
Forest (Evergreen)	3385	4435	4847	6362
Forest (Deciduous)	3385	4435	4847	6362
Vegetation	11059	9230	9277	12457
Mangroves	5878	5911	4350	3852

Table 3.2(B): Area of SGNP- ArcGIS Maps

Name	Area (Hectare)			
	Year - 1978	**Year - 1987**	**Year – 2000**	**Year - 2020**
Forest (Evergreen)	2008	2992	3417	4515
Forest (Deciduous)	2008	2992	3417	4515
Vegetation	2693	2209	1830	1568
Mangroves	2467	2247	1178	189

Table 3.3: Calculation of Biomass based on SGNP [3], [4]

Name	Standing Biomass (t/ha)	Biomass (tonnes) (Standing Biomass * Area)			
		Year - 1978	**Year - 1987**	**Year - 2000**	**Year - 2020**
Forest (Evergreen)	485	974006	1451275	1657696	2190073
Forest (Deciduous)	258	518131	772018	881825	1165028
Vegetation	74.25	199993	164068	135928	116449
Mangroves	213.8	527615	480511	251916	40581
Total		2219746	2867873	2927366	3512132

Table 3.4: Calculation of CO_2 Sequestration and TCC based on SGNP [3]

Name	YEAR - 1978	YEAR - 1987	YEAR – 2000	YEAR - 2020
Carbon Absorbed (Total biomass * 0.5)	1109873	1433936	1463683	1756066
CO_2 Sequestration (Carbon Absorbed * 3.67)	4073235	5262548	5371718	6444763

Tourism Carrying Capacity (CO_2 Sequestration * r)	**130343**	**168401**	**171894**	**206232**

Calculation – Year 2020

Area of Forest (Evergreen) = 4515 ha

Standing Biomass = 485 t/ha [4]

Biomass = Area * Standing Biomass [3]

= 4515 * 485

= 2190073 tonnes

Total biomass = 3512132 tonnes

Carbon Absorbed = Total biomass * 0.5 [3]

= 3512132 *0.5 = 1756066 tonnes

CO_2 Sequestration = Carbon Absorbed * 3.67 [3]

= 1756066 *3.67 = 6444763 tonnes

TCC = CO_2 Sequestration * r [3]

= 6444763 *0.032

= 2,06,232 footfall

The total footfall value observed for the study from Environmental Management Plan of SGNP 2000 was 1466359 while the calculated footfall values by CO_2 sequestration method is found to be 206232. While the value of actual footfall seems to be high, it is necessary to understand the actual number of visitors spending whole day in SGNP, peak time for visitors and related parameters and normalise this value of actual footfall accordingly so that correct comparison with the carrying capacity value can be made.

3.2 Calculation of Water Environment Carrying Capacity (WECC)

The WECC calculations are done below based on data assorted from Environmental Management Plan for SGNP 2000 for Vihar and Tulsi lakes and are based on utilization ratio.

Table 3.5: Baseline Data of Water [2]

Lake	Volume of water (m^3)	Consumption of water (MLD)
Vihar Lake	42000000	68

Tulsi Lake	10430000	18

$$UR_{\text{Available Water Resources}} = \frac{\textit{Amount of Water Consumed}}{\textit{Total Available Water Resources}}$$

Amount of water Consumed = 18 + 68 = 86 MLD

= 86000 m^3/day

= 31390000 m^3/year

Total Available Water Resources (Year) = (42000000 + 10430000) = 52430000 m^3

Therefore,

$$UR_{\text{Available Water Resources}} = \frac{\textit{Amount of Water Consumed}}{\textit{Total Available Water Resources}}$$

= (31390000 / 52430000) *100

= 59.87 %

The utilisation ratio of available water resources in SGNP is 59.87% which is less than the reference value of 100%. While 100% indicates that the carrying capacity has reached, the idea is to never reach 100% and sufficient measures should be applied to keep the utilisation ratio within the range of current assessment i.e. 60-65%. This also calls for regular monitoring of WECC, so that if UR is increasing, corrective measures should be applied to restore the balance.

3.3 Calculation of Noise Carrying Capacity (NCC)

For Noise level calculations 3 areas were selected and noise level ranges used from Environmental Management Plan SGNP 2000 for these selected regions for three seasons. The values are compared with CPCB standards for silence zone. The following tables below shows the noise level measured in SGNP vis- a- vis CPCB Noise standards,

Table 3.6: Seasonal Baseline Noise Level Data in Study Area [2]

Location	Season	Noise Levels dB (A)	
		Day Time	**Night Time**
Tulsi lake	Winter	35-36	30-36
	Summer	39-47.3	38-39.5
	Post Monsoon	41-56	39-47
Yeur Village	Winter	33-56	34-47

	Summer	39-58	38-41
	Post Monsoon	40-58	39-50
SGNP Entrance	Winter	35-61	35-46
	Summer	39.5-65.3	37-49.5
	Post Monsoon	40-60	38-53

Table 3.7: CPCB Noise Standards [2]

Category of Area	Limits in dB (A)	
	Day Time	**Night Time**
Industrial Area	75	70
Commercial Area	65	55
Residential Area	55	45
Silence Zone	**50**	**40**

The maximum noise level measured during daytime near Tulsi lake during post-monsoon, Yeur village and SGNP Entrance gate in all seasons are showing values greater than the day time limits of CPCB for silence zone. Likewise, the maximum noise level measured during night time near Tulsi lake during post-monsoon and in all seasons for Yeur village, SGNP entrance exceeded the night time limits of CPCB for silence zone. However, overall noise levels are within the limit except for the SGNP entrance gate due to high traffic flows and other human activities.

3.4 Calculation of Air Carrying Capacity (ACC)

The values of air pollutants such as SO_2, NO_2, SPM and RSPM measured in the SGNP environment, available in Environmental management plan for SGNP 2000 are considered and compared with NAAQS for each pollutant to calculated the Utilization ratio for AECC calculation,

$$UR_{SO2} = \frac{7.3}{15} * 100 = 48.66\ \%$$

$$UR_{NO2} = \frac{32.7}{30} * 100 = 124\ \%$$

$$UR_{SPM} = \frac{162}{100} * 100 = 162\ \%$$

$$UR_{RSPM} = \frac{105}{75} * 100 = 140\ \%$$

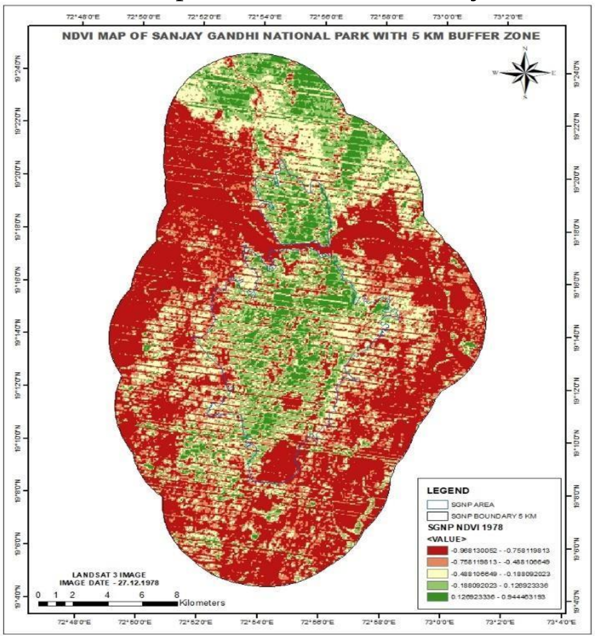
The utilization ratio for air calculated should be within the reference value of 100% so that the resource is not overused and environment is not overloaded. However, calculation reveal that air pollutant (except SO_2) are exceeding the Utilization ratio beyond 100 %. The main sources are vehicular emissions and other anthropogenic activities in the vicinity.

3.5 Assessment of Environmental Attributes for ECC

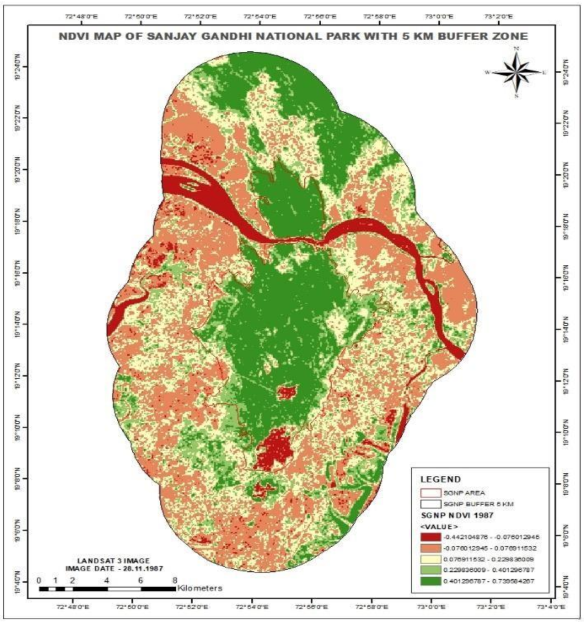
For the study area of SGNP, GIS and Remote Sensing based ecological parameter maps are generated with 5 km buffer Zone and are analyzed for the ECC assessment. The study objectives also extend this approach to the core zone in the near future. The different parameters analysed are presented below,

3.5.1 Normalized Difference Vegetation Index (NDVI) of SGNP

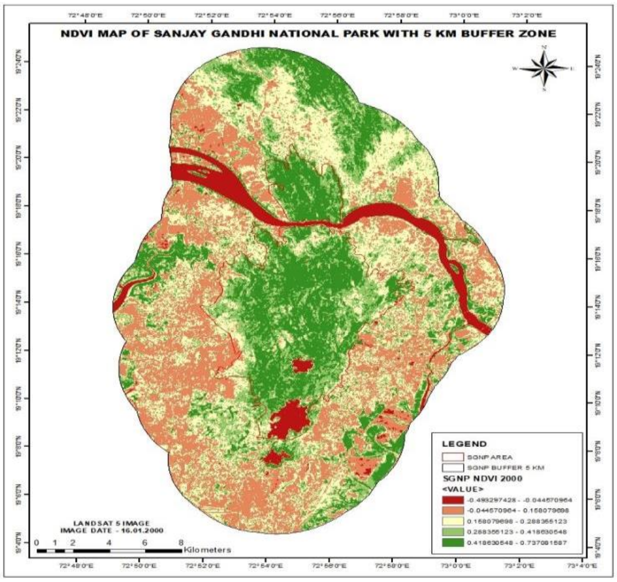
The maps of NDVI of the study area for the different years is shown below,



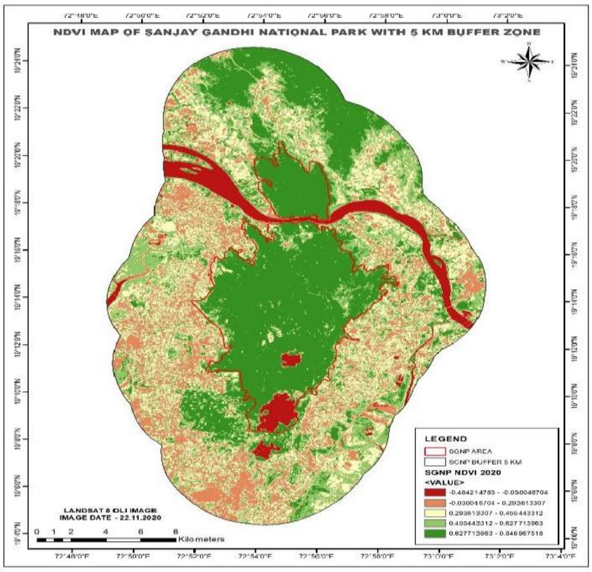
(a)



(b)



(c)



(d)

Fig. 3.2 Normalized Difference Vegetation Index (NDVI) of SGNP: (a) 1978, (b) 1987, (c) 2000, (d) 2020

For Landsat 4-7, NDVI = (Band 4 – Band 3) / (Band 4 + Band 3) and For Landsat 8, NDVI = (Band 5 – Band 4) / (Band 5 + Band 4) are used.

The details about the NDVI data for SGNP is as follows:

Table 3.8: Details of NDVI Map

Data extracted from	**Date**	**Non vegetative area (Sq.km)**	**Vegetative area (sq.km)**
Landsat 8 OLI	22.11.2020	250.88	300.32
Landsat 5	16.01.2000	325.86	225.34
Landsat 3	28.11.1987	331.56	219.63
Landsat 3	27.12.1978	435.16	116.03

The comparison of NDVI values of SGNP from 1978 to 2020 shows a positive increase in vegetation area from 116.03 Sq.km to 300.32 sq.km. It indicates that vegetation cover of SGNP increased over the years which is a good sign for the enhancement of carrying capacity.

3.5.2 Normalized Difference Water Index (NDWI) of SGNP

The map of NDWI of the study area is shown below,

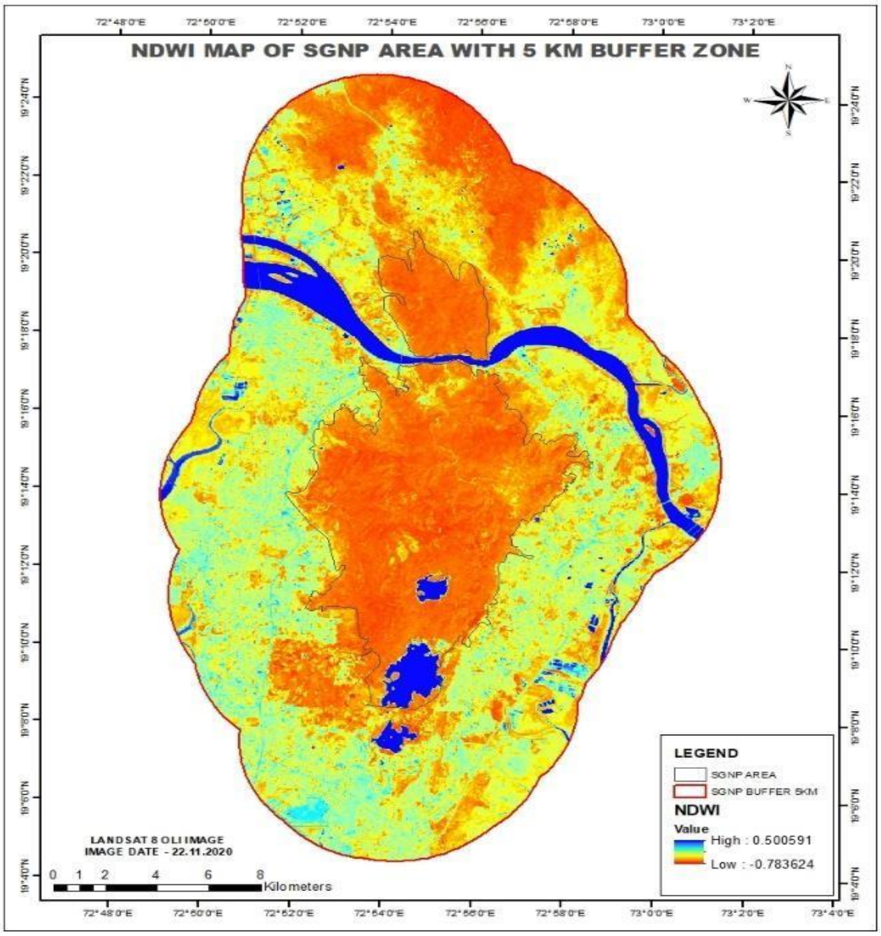


Fig. 3.3 Normalized Difference Water Index (NDWI) Map of SGNP

NDWI value of SGNP area dated 22.11.2020 shows a low value of -0.78 to a high value of 0.5. High values indicate water body while low values indicate dry land.

3.5.3 Land Stress Index (LSI) of SGNP

The map of LSI of the study area is shown below:

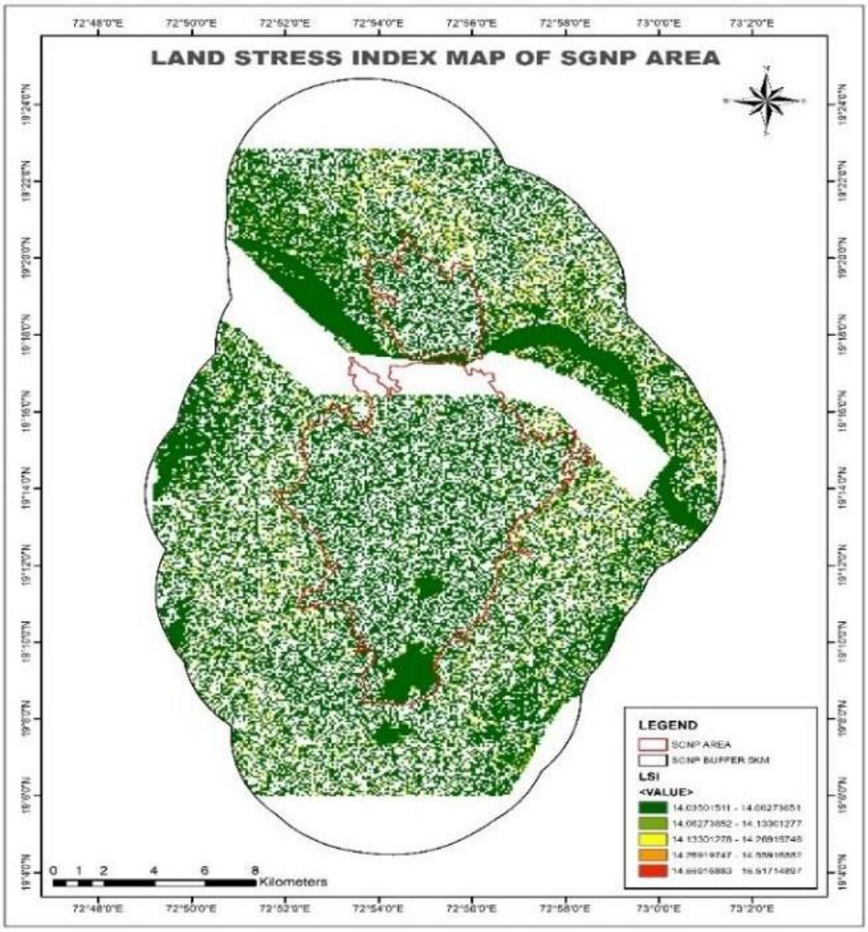


Fig. 3.4 Land Stress Index (LSI) Map of SGNP

The approximate areas of LSI in SGNP (in Sq. Km) are as follows:

Table 3.9: Details of Soil Erosion Classification:

LSI	Very Low	Low	Moderate	High	Very High
Area (Sq.km)	266.16	0.91	0.13	0.03	0.02

The above data depicts that most of the area of SGNP comes under very low land stress index and less chances of erodibility.

3.5.4 Slope Map of SGNP

The slope map of the study area is shown below,

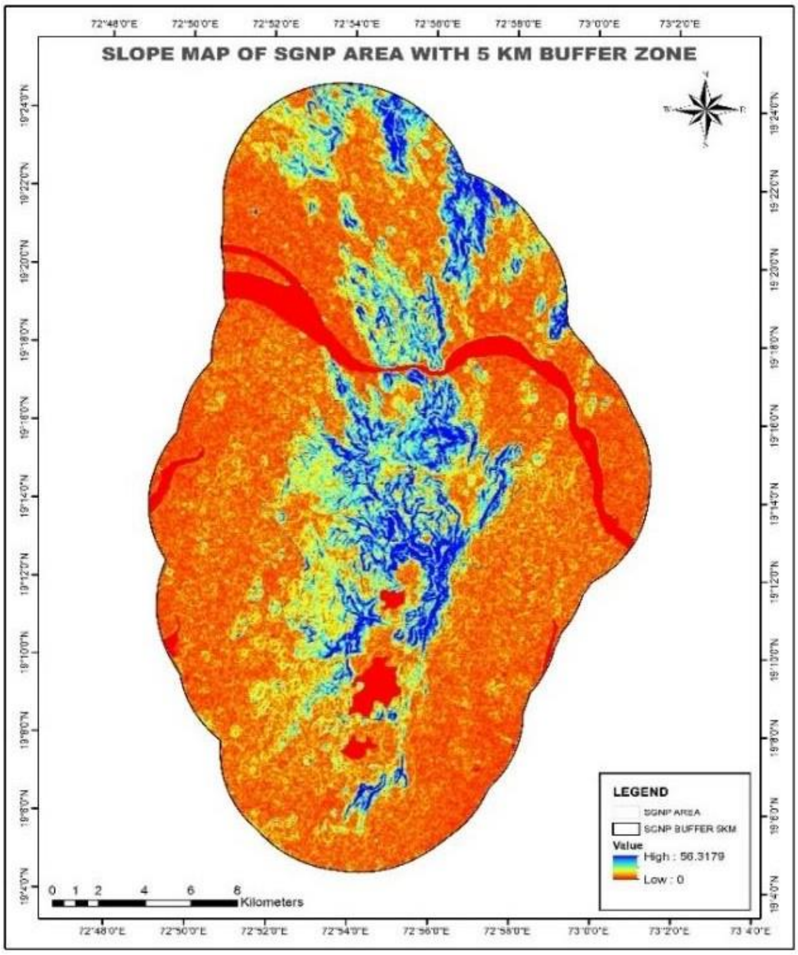
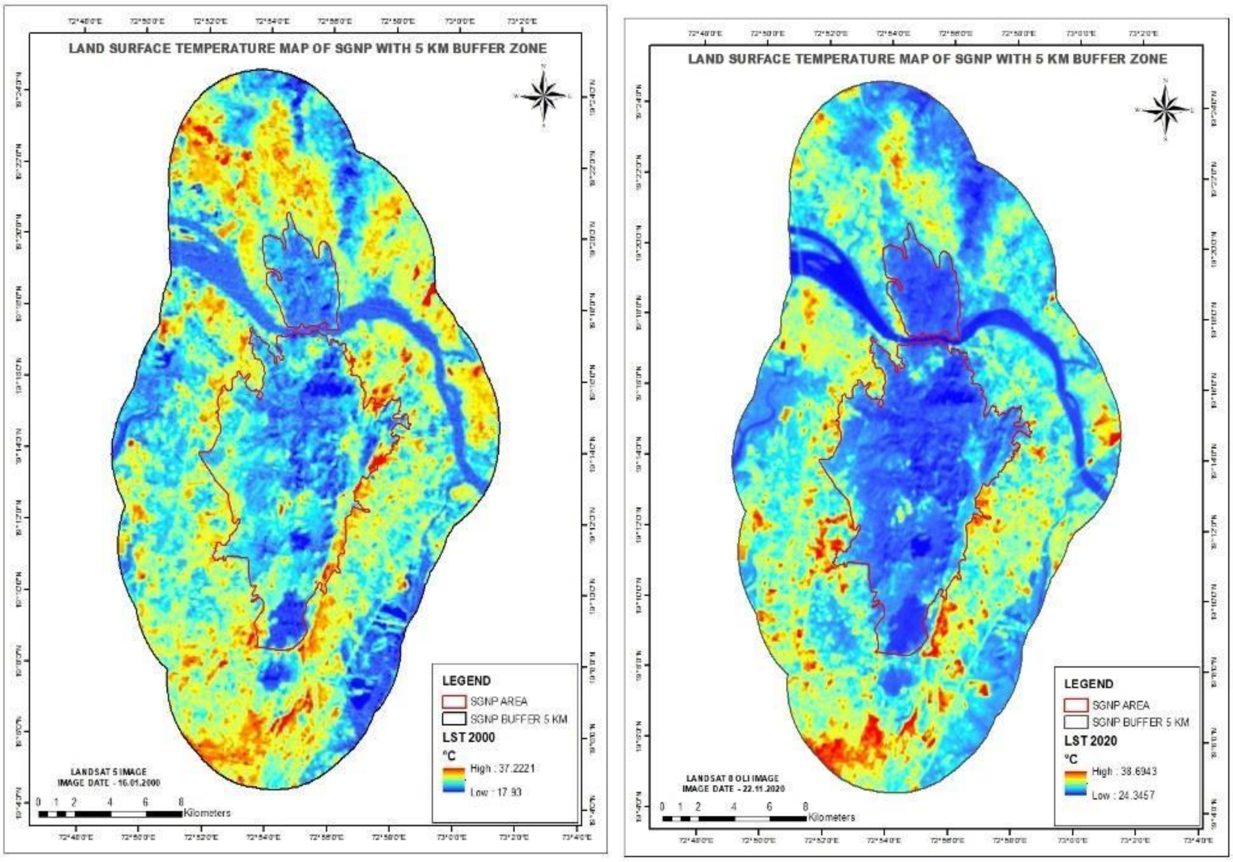


Fig. 3.5 Slope Map of SGNP

Slope values of SGNP ranges from 0 to 56.31. Lower values indicate low altitude area while higher values indicate high altitude areas.

3.5.5 Land Surface Temperature (LST) of SGNP

Landsat 5, 8 data are used to calculate the Land Surface Temperature of SGNP area and the image dates are 22.11.2020 & 16.01.2000. The LST maps of SGNP displays that Land surface temperature has increased in 2020 when compared to 2000.The lowest temperature reported in 2000 was 17.93^{0}C which has increased to 24.34^{0}C in 2020. The LST map of the study area for year 2000 and 2020 is shown below,



(a) (b)

Fig. 3.6 Land Surface Temperature (LST) Map of SGNP: (a) 2000, (b) 2020

3.5.6 Habitat Quality Index (HQI) of SGNP

HQI is mainly used to evaluate the suitability of the habitat quality of the main protected species in nature reserves. The Habitat Quality Index map of SGNP have a higher value of 267.74 and a lower value of 74.28. Higher values indicate high habitat suitability and lower values indicates low habitat suitability based on habitat quality. Most of the area of SGNP have higher HQI values hence greater habitat suitability for wildlife population. The HQI map depicting the study area is shown below.

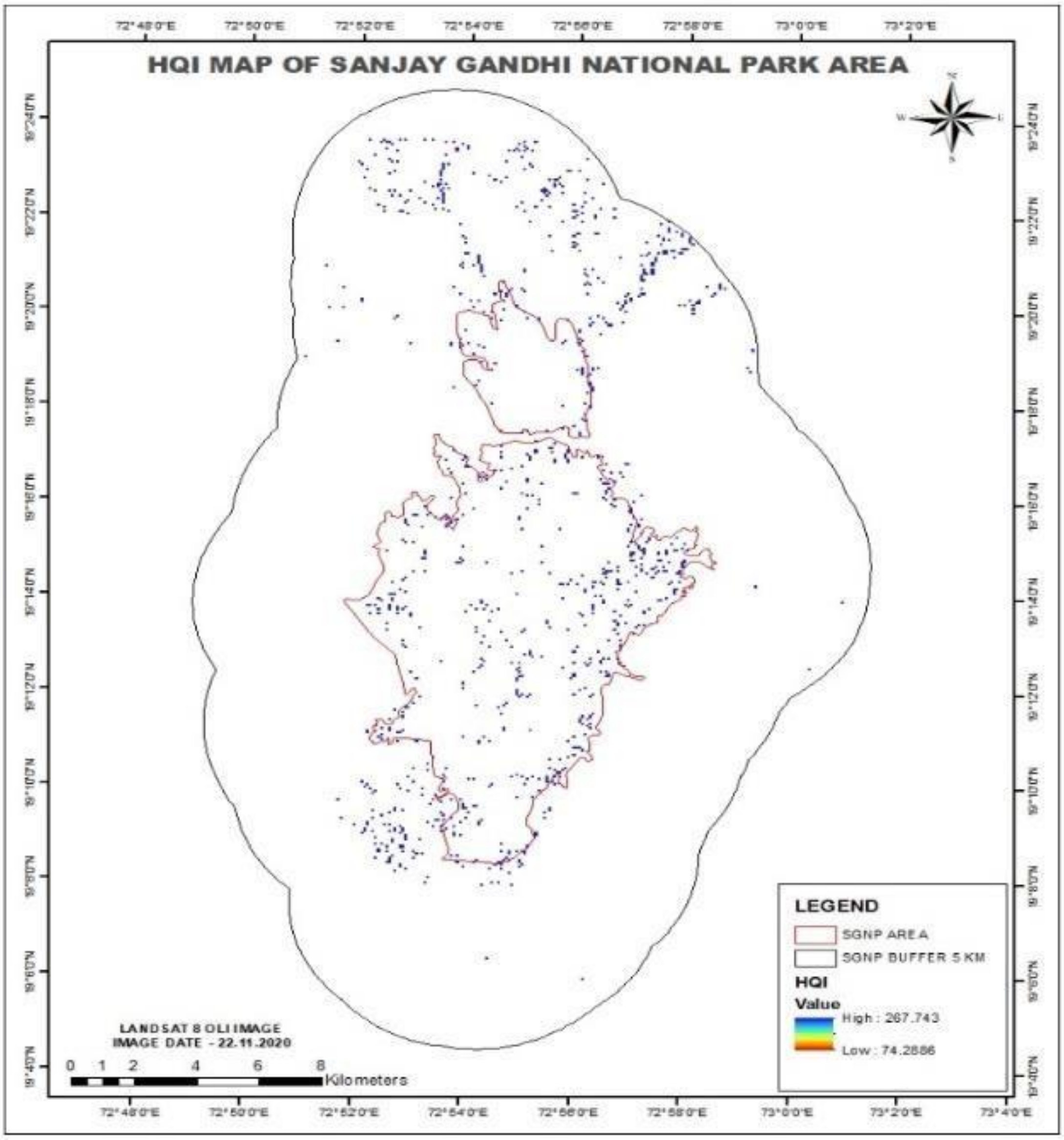


Fig. 3.7 Habitat Quality Index (HQI) Map of SGNP

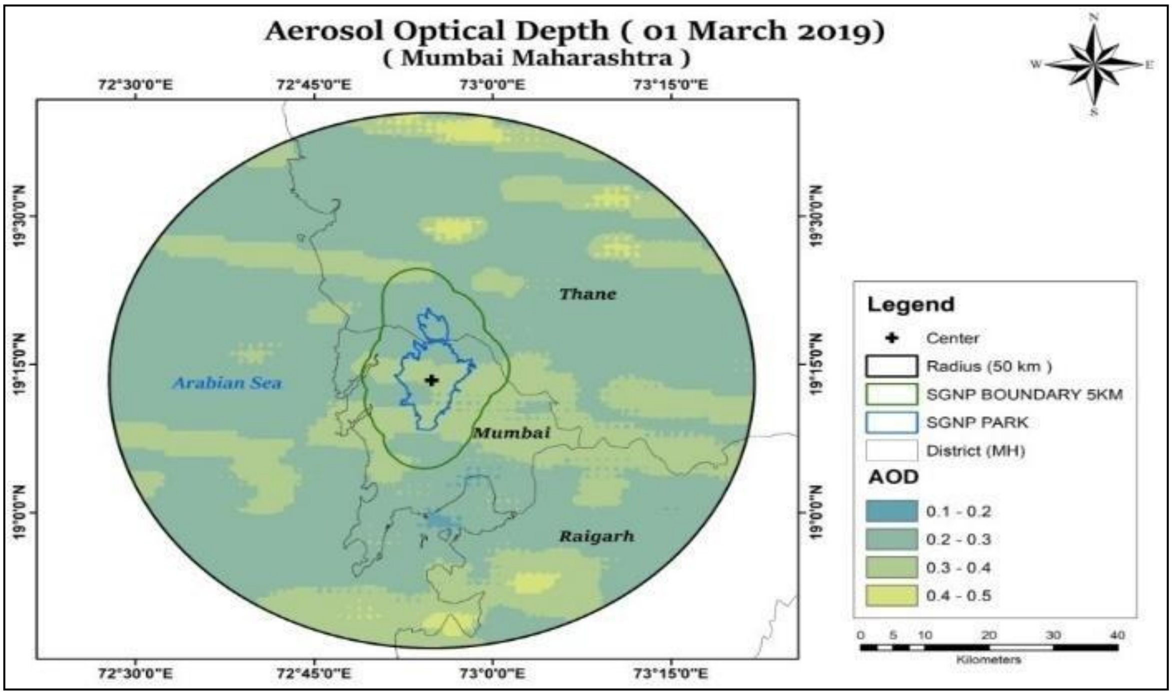
3.5.7 Aerosol Optical Depth (AOD) and $PM_{2.5}$ of SGNP,

For the analysis of the aerosol optical depth and $PM_{2.5}$ data is extracted from AOD_{MODIS} with a spatial resolution of 3 km. The study area is extracted using ArcGIS tools. The details of the map are shown in the table below,

Table 3.10: AOD and $PM_{2.5}$ at Sanjay Gandhi National Park,

Sr. No	Date	Aerosol Optical Depth (AOD)	Particulate Matter - $PM_{2.5}$ ($\mu g/m^3$)
1	01-Mar-19	0.29	45.11
3	04-Dec-19	0.02	14.36

The mean values of AOD and $PM_{2.5}$ are showing variations. The estimate indicates higher anthropogenic activities coupled with poor meteorological conditions. The map showing the details of aerosol optical depth and $PM_{2.5}$ is shown below. Detailed analysis of AOD and PM2.5 with better time resolution and continued monitoring is necessary.



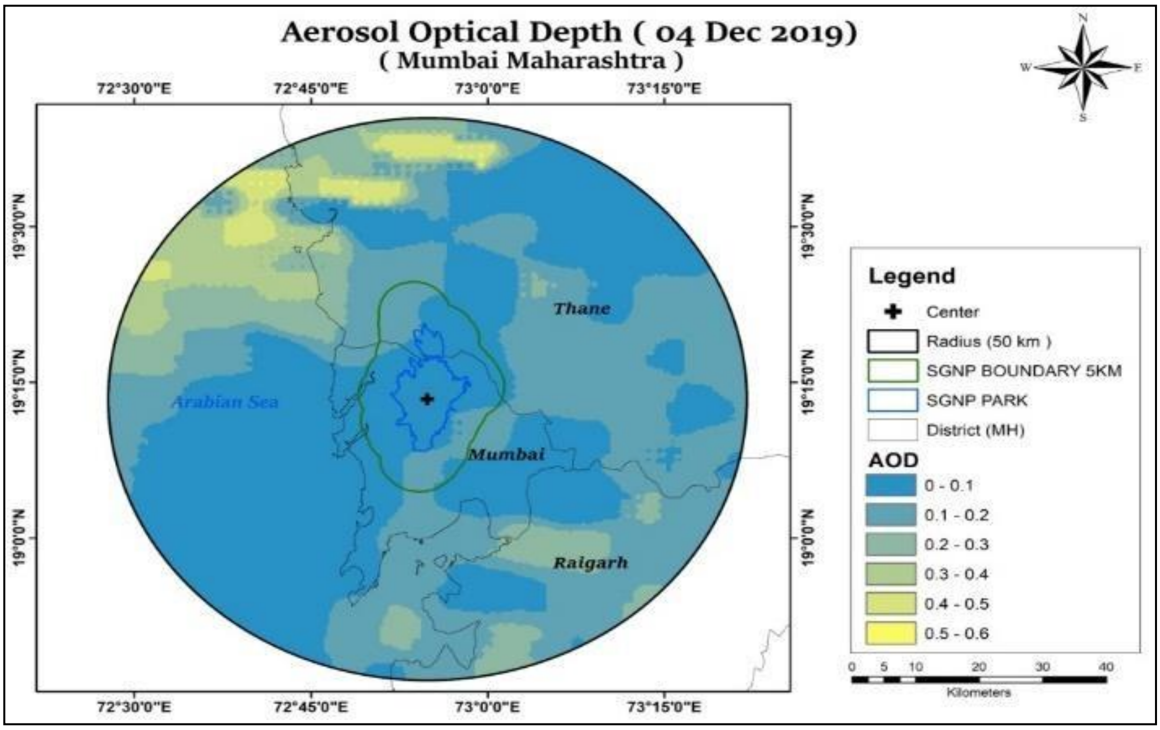


Fig. 3.8 Aerosol Optical Depth Map of SGNP

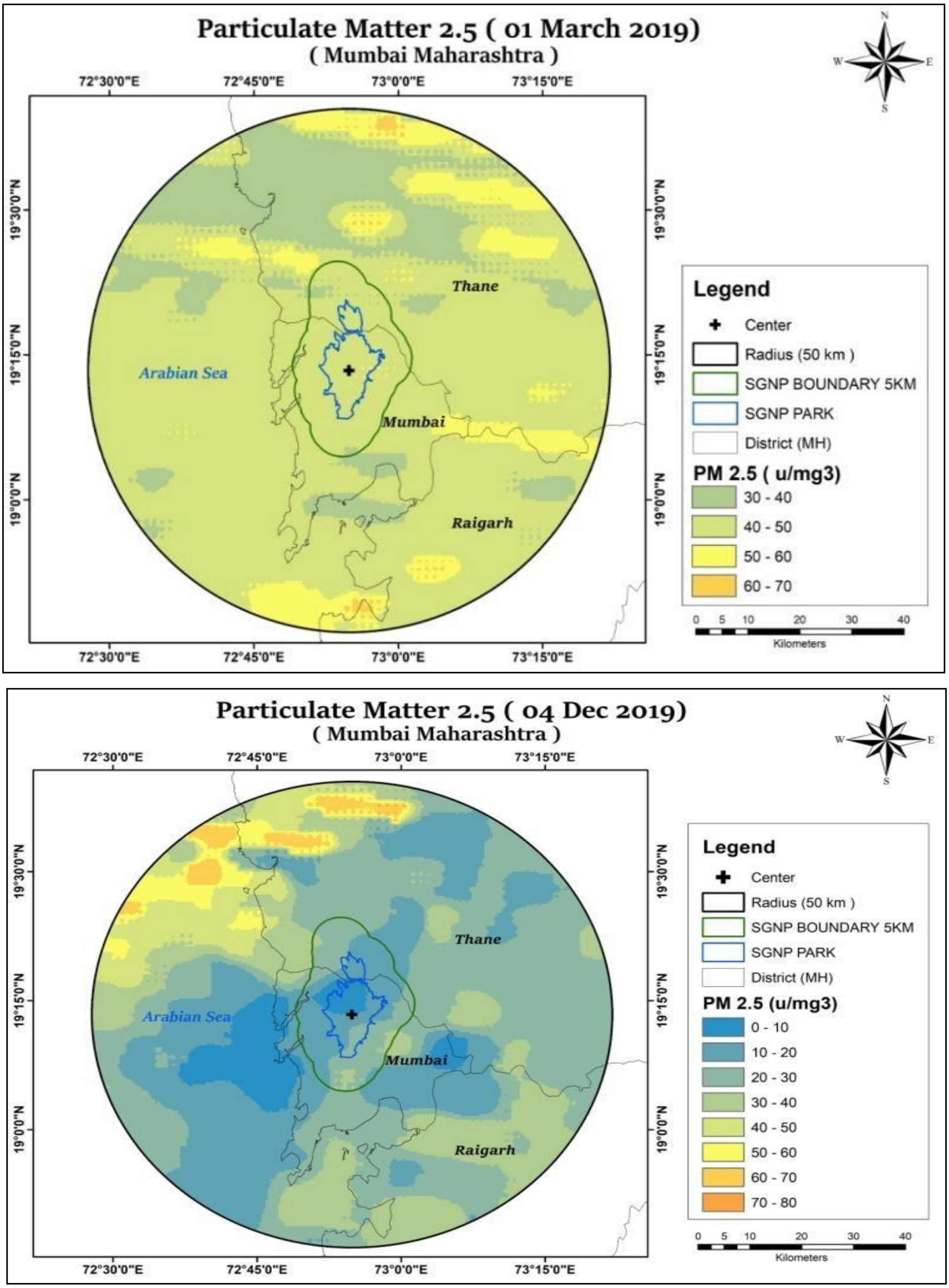


Fig. 3.9 Particulate Matter $PM_{2.5}$ Map of SGNP

From the analysis of above environmental attributes, it is observed that certain parameters have been impacted higher. Parameters such as land use, air pollution, AOD, $PM_{2.5}$, and Noise might be under environmental pressure while other factors such as biomass, forest, NDVI, NDWI are comparatively better. However, this is preliminary analysis based on secondary data and needs to be substantiated with primary data and in-depth analysis which will be attempted during second phase of the study.

4.0 Way Forward

In order to understand the carrying capacity of the SGNP in depth, the critical environmental attributes are to be weighed scientifically. Methods, including but not limited to, modelling, fuzzy, hierarchical techniques will be applied in the next step to derive conclusive assessment on environmental carrying capacity of SGNP.

A detailed study using other modelling techniques shall be carried out during next phase of the study, the extent of utilization will be assessed using weightage of different factorial layers and sub- criteria. Assessment in reference to the impact to faunal diversity of the park will also be attempted during the detailed planned study.

There are certain aspects of the study which requires subsequent detailed analysis. It includes secondary data collection of remaining parameters, primary survey for certain parameters, assessment of habitat suitability, ECC with respect to Air, Water and Noise environment by keeping faunal biodiversity impacts at the center and select ground validation points for remotely sensed data. Overall analysis of ECC using AHP or Fuzzy method based on the above additional parameters, data and validation points will be done.

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Item No. 02 &03 Court No. 1

BEFORE THE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH, NEW DELHI

Original Application No. 462/2018

(Earlier O.A. No. 11/2018 (SZ)

WITH

Original Application No. 76/2015 (SZ)

D. V. Girish Applicant(s)

Versus

Union of India & Ors. Respondent(s)

With

D. V. Girish Applicant(s)

Versus

The Member Secretary, National Tiger
Conservation Authority, MOEF & Ors. Respondent(s)

Date of hearing: 19.03.2020

CORAM: **HON'BLE MR. JUSTICE ADARSH KUMAR GOEL, CHAIRPERSON**
HON'BLE MR. JUSTICE SHEO KUMAR SINGH, JUDICIAL MEMBER
HON'BLE DR. NAGIN NANDA, EXPERT MEMBER

ORDER

1. The issue for consideration is undertaking of carrying capacity assessment of eco-sensitive zones to give effect to the principle of 'Sustainable Development'. This Tribunal issued directions on 30.07.2018 to the Ministry of Urban Development and the MoEF&CC and the corresponding authorities in all the States. Thereafter on 03.04.2019, the Tribunal considered the affidavit filed by the MoEF&CC dated 27.03.2019 and observed:

> *"3. The MoEF & CC had filed an affidavit dated 27.03.2019 and submitted that they are taking steps to study the matter and also getting views from the States and the concerned Department but the exercise could not be completed and they require 6 months more time for this*

purpose. The order was passed in the month of July, 2018. Nearly more than eight months lapsed after the order but nothing fruitful has been done by them and MoEF & CC has not taken seriousness about the issue as considered by the Tribunal.

4. *On going through the affidavit, it is seen that no substantive work has been done for preparing the report as directed by this Tribunal. Considering this aspect, we feel that some time can be granted but same cannot be as requested by them.*

5. *We feel that 3 months time can be granted and they are directed to file a report regarding progress of the study taken by them on monthly basis by Email and if the Tribunal is satisfied with work done by them and if they require further time that can be considered after expiry of 3 months fixed by this Tribunal. Reports shall be filed to this Tribunal through email at ngt.filing@gmail.com."*

2. Thereafter on 25.09.2019 on further consideration, the Tribunal observed:

"10. In the meantime the MoEF & CC and Ministry of Urban Development may complete the study and prepare national policy as to how this will have regulated as directed by this Tribunal as per order in O.A. No. 462/2018 dated 30.07.2018.

11. The Joint Secretary, MoEF & CC was present today. He explained that a draft template has been prepared for circulation and they need to consult the Ministry of Urban Development for approval of the same and thereafter it will circulated among the States, then final guidelines will be issued. They are directed to submit a further report on this aspect before the next date of hearing."

3. In pursuance of the above, an affidavit has been filed by the MoEF&CC on 31.01.2020 as follows:

"5. The draft guidelines/template prepared by the Ministry was circulated to G.B Pant National Institute of Himalayan Environment & Sustainable Development, Almora, Uttarakhand, Ministry of Housing Affairs, Town & Country Planner, Town & Country Planning Organization (TCPO), New Delhi and School of Planning and Architecture, New Delhi. Based on the comments received on the template, a meeting was held on 25th November, 2019 in the Ministry of Environment, Forest and Climate Change, wherein the officials from the above

organizations were present. During the meeting all components/parameters of draft template assessing Carrying Capacity of Town/Hill Station were discussed. Accordingly, the structure of the template was finalized.

6. The G.B Pant National Institute of Himalayan Environment & Sustainable Development, Almora, Uttarakhand has submitted a report, which was examined in the Ministry and finalized. A copy of guidelines has been circulated to all State Governments and UTs."

4. In view of the above, further steps need to be taken in the matter. It should be possible to undertake carrying capacity of at least one eco-sensitive area in every State/UT in the first instance within three months. The CPCB may coordinate with the concerned authorities, including the State Administration, for undertaking carrying capacity assessment of at least one eco-sensitive area in the State, which may be thereafter replicated for all the eco-sensitive areas in next three months. The CPCB is at liberty to associate any individual/organization for the purpose and utilize compensation funds available with for this purpose.

5. Let a further report in the matter be filed before the next date by email at judicial-ngt@gov.in.

6. A copy of this order be sent by email to CPCB.

List for further consideration on 14.10.2020.

Adarsh Kumar Goel, CP

Sheo Kumar Singh, JM

Dr. Nagin Nanda, EM

March 19, 2020
Original Application No.462/2018
with Original Application No. 76/2015
AK