

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)

D. V. Girish

Applicant

Versus

Union of India & Ors.

Respondent(s)

With

D. V. Girish

Applicant

Versus

The Member Secretary National Tiger
Conservation Authority, MoEF & Ors.

Respondent(s)

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| 1. | Final Report on "Assessment of Environmental Carrying Capacity of Eco – sensitive Zone: Sanjay Gandhi National Park, Mumbai, Maharashtra" in compliance to the Hon'ble NGT order dated 19.03.2020 in Original Application No. 462/2018,(Earlier O.A. No. 11/2018 (SZ) with Original Application No. 76/2015 (SZ), D.V Girish Vs. Union of India & Ors. with D.V Girish Vs. The Member Secretary National Tiger Conservation Authority, MoEF & Ors. | |
| 2. | Annexure-I: A copy of Hon'ble NGT order dated 19.03.2020. | |


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Date: 03.12.2021

Place: Delhi

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



Submitted to:

Central Pollution Control Board (CPCB)



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(July 2021)

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1.0 Introduction

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 desert which is located around 25 km north of Mumbai city and 8 km from the shores of Arabian Sea [1]. It lies between 72° 53' & 72° 50' East longitude and 19° 88' & 19° 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 has a total area of 103.09 square kilometres, 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°C 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, 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 city. Many illicit 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 as of now have been surpassed in a few zones, and thus, it has become essential to evaluate the

carrying capacity of SGNP.

In the preliminary report, the environmental attributes such as air, water, habitat, noise, land, flora, and fauna of SGNP were studied along with tourism activities prevailing there and considered as indicators for the assessment of the Environmental Carrying Capacity (ECC) of SGNP. Carrying capacity is a term that has been used to quantify the impact of socioeconomic human activities and the natural environment.. This has been captured through the ability of environment to support the human activities by understanding the relationship that exists. The estimation of ECC helps in identifying the relation with its effect between the existing environment and the growth oriented human activities. This whole system can be described under two major forces, supporting forces and the pressure forces. The supporting forces can be named as the ecological resilience and pressure forces as ecological pressure. The ecological resilience was studied through soil erosion, land cover and climatic factors while ecological pressure has been captured under air pollution and urban heat island effect. This pressure forces are further described through parameters (or evaluation factors) which has been elaborated further. In this study the ECC has been estimated in such a way that the critical parameters affecting environment of Sanjay Gandhi Park has been included. The study uses fuzzy analytic hierarchy process (f-AHP) to estimate the ECC.

1.1 Objectives of the Study

The study's major goal is to perform the carrying capacity assessment of 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 such as areal extent, geographical features, flora and fauna, and the tourist activities prevailing there.

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

1.2 Stages of the study

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

Selection of suitable methodologies: The carrying capacity assessment of SGNP can be evaluated by sectioning the environment into several components, which include Land, Air, Water, Habitat, Biodiversity along with 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 analysed 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.

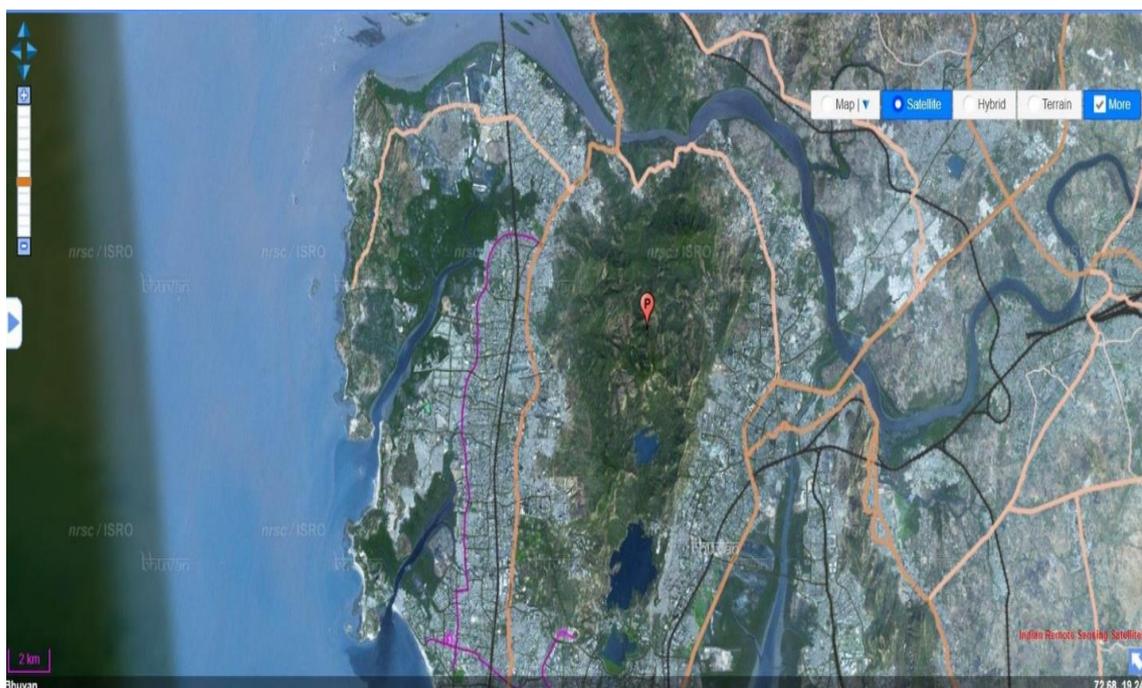


Fig. 1.1: Location of the study area-SGNP, Mumbai-Maharashtra (Bhuvan Map)

2.0 Methodologies for Assessment of Environmental Carrying Capacity

Environmental Carrying Capacity (ECC), or specifically ecological carrying capacity in this case of eco-sensitive zone, estimation for the region is important to ascertain the limits of development within the sustainable framework. This is especially significant in light of the United Nations' 2030 Sustainable Development Goals. Goal 15: Preserve, recover, and encourage the sustainable usage of terrestrial ecosystems; conserve biodiversity sustainably; prevent desertification; and prevent soil erosion and loss of biodiversity.. 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 and in turn, the public at large. 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 forces for the ecosystem.

The methodology to be followed for estimating ECC of study area can be understood and done as per the flowchart:

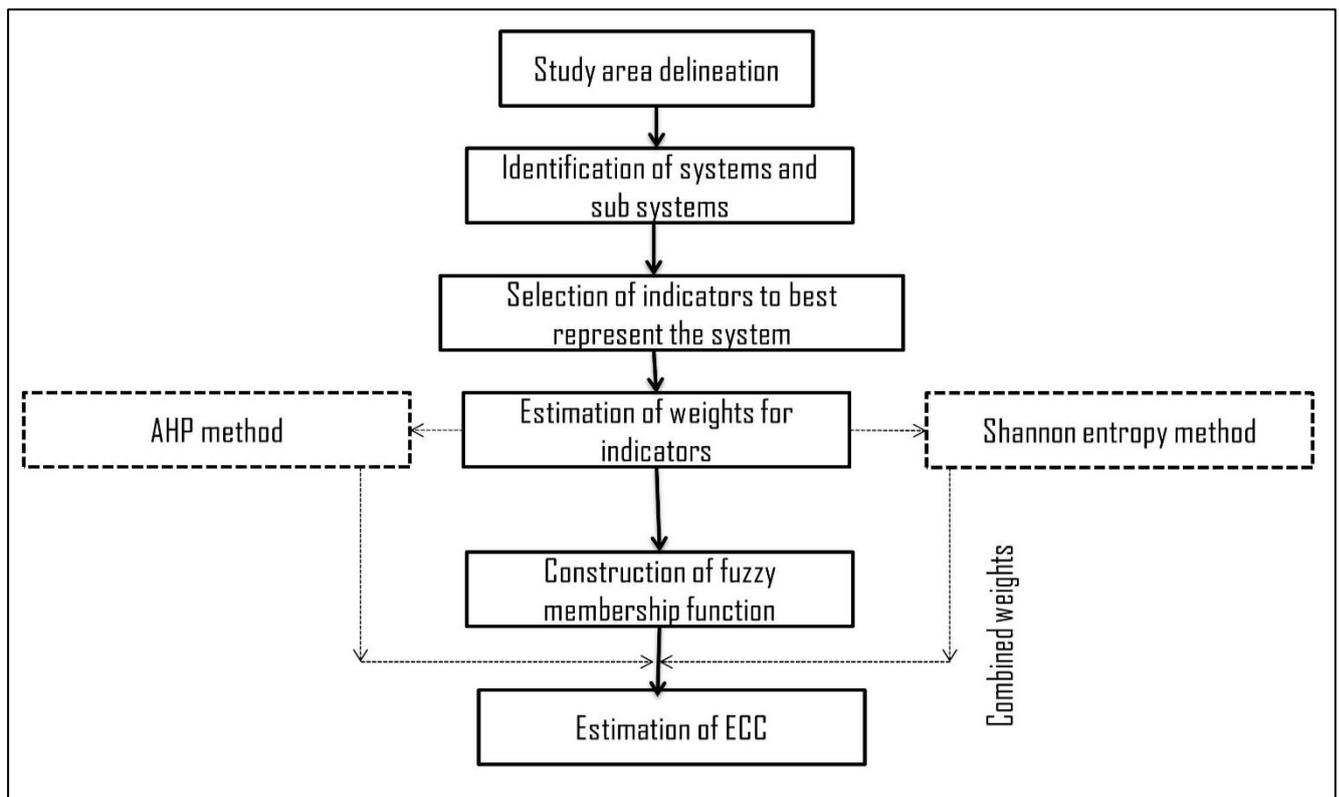


Fig. 2.1: Flowchart Showing methodology for estimating ECC

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 study area represented by a categorical selection of processes for ecological resilience and ecological pressure needs to be quantified for estimating ECC. This study can use 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), and for pressure, the selected ones are 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, processes and amongst each other. 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 estimations of ECC, and a map representing such variations becomes handy for regional development. [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. Here 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 control some activities around

national parks and wildlife refuges in order to reduce detrimental impacts on the fragile ecosystem surrounding them. Protected places benefit from Eco Sensitive Zones, which are designed to act as a "shock absorber." In this case, the buffer zone is used to map the environmental attributes in and around the SGNP. The raw area of SGNP and the buffer area should given information for assessment of ECC.

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

2.1 Water Environment Carrying Capacity (WECC)

Water is essential to all life and 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 of water incorporates agricultural, industrial, household, recreational and environmental activities. Technologies such as recycling and desalination processes are also used to provide fresh water to society [7]. Contradictions between the environment, population, and social development have become more obvious as a result of rapid population growth and ongoing economic development. As a result, resolving these inconsistencies has become a major topic in water resource studies, and the study of WECC is at the heart of any environmental sustainability and water security policy.

The SGNP consists of lakes, major & minor streams, waterholes, and wells as its water resources. 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 cities and wildlife population, its water resource carrying capacity assessment is a necessity of this hour.

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 our study [2]. The available water resources can be defined as the

maximum water resources that may be exploited without causing harm to the environment. It is defined as the sum of surface water, groundwater, trans-boundary water, and reclaimed water that is locally available. The quantity of accessible water supplies was determined using an estimated total of atmospheric and water source technical conditions, as well as a quota set by higher-level administrations. [7]. It is estimated by using the following equation.

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

Where, E_{ws} = Quantity of available water resources

W_s = Total available surface water

W_g = Quantity of available groundwater

W_t = Total transfer water from cross-boundary regions

W_{uc} = Reclaimed water sources including wastewater recycling

Data related to the quantity of water taken for utilization 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 used to investigate how much WECC was used by the economy. The UR of available water resources can be estimated by using the equation given below [7].

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

If $UR > 100\%$, the resources are overused, or the ecosystem is being overburdened. [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. The oxygen within the air is essential for the creatures to survive since we utilize this oxygen to create energy from the nourishments we eat. The air also plays an essential role in regulating the earth's temperature and causes different weather patterns. Polluting the air environment by discharging hazardous chemicals hence debilitates life and can change climatic patterns. Many air contaminants, including tropospheric O_3 and NO_x , interact with carbon emissions fixation by the tree canopy by affecting the metabolic activity of the plants.. Air pollution can affect wildlife indirectly by changing plant communities. There are two basic ways that destroy animals which are depicted below:

- It has an impact on the ecosystem or habitat where they dwell.
- It has an impact on the food supply's quality and quantity.

Air Environment Carrying Capacity (AECC) Estimation

For the assessment of AECC of SGNP, details about the sources in the vicinity and within the park are evaluated. 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 SO₂, NO₂, SPM, and RSPM emitted, is compared with NAAQS values of sensitive regions, and the Utilization Ratio is estimated for each air pollutant.

$$\text{Utilization Ratio (UR)} = \text{Amount of pollutant load/ECC}$$

When the utilization ratio is greater than 100%, the resources are overused, or the environment is overloaded.

2.3 Tourism Carbon Carrying Capacity (TCC)

Tourism has been one of the fastest-growing economic sectors in the world, yet it also has the highest carbon emissions. Tourism is responsible for 5% of global carbon emissions, significantly impacting global warming [3]. Moreover, tourism can cause significant disturbances to animals in their natural habitats. More people engage with wildlife as wildlife tourism grows in a certain location. This can be a serious issue because certain wild animals dislike being around people, and humans frequently leave trash and other things that might harm a species' environment.

Because of such ecological and environmental problems, the TCC value for SGNP must be calculated since it is one of the major national parks within a 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 of SGNP are assorted [2] and the carbon carrying capacity which refers to the quantity of fixed CO₂ engrossed by various vegetation's in a zone each year is used for calculations. [3].

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

The TCC is calculated by using the following equation.

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

$$TCC = CC \times r \quad [3]$$

Where, CC = Region's carbon carrying capacity,

S = Area of forest,

C_{NEP} = Amount of carbon absorbed by vegetations 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, much like accessibility of building materials or sources of food, is critical to the ecosystem's survival. The auditory environment is critical for activities including identifying desirable habitat and partners, avoiding predators, safeguarding the young, and developing territory.

Sound is what we hear, but noise is the unwanted sound. In general, a rising number of studies show that noisy surroundings stress animals, much as they do humans. Noise pollution makes it more difficult for them to do these duties, which has a negative impact on their ability to survive. Caterpillars' hearts beat quicker and bluebirds have fewer offspring when they hear loud noises, according to studies.. Hence, a detailed study should 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 which is a green oasis with its rich biodiversity, its picturesque landscape, its lakes and stream and act as a respite to millions of inhabitants of Mumbai city from the drudgery of a hectic yet monotonous existence.

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 (L_{eq} in dB) [5] remains within the prescribed noise level standard limits as decided by CPCB for Silence Zones.

The above factors of Noise, Air, Water and Tourism are critical for carrying capacity and above 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)

The heat transfer at the earth's surface and within the planetary boundary layer is influenced by greenery, which often mitigates local temperature extremes. 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 which is the foundation 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 can be prepared and are used to study any decrease in its vegetative cover by comparing the maps.

The normalised difference vegetative index (NDVI) is a simple graphical indication used to examine remote sensing measurements, typically from a space platform, to determine if the observed target has live green vegetation. The NDVI scale is used to measure the healthiness of greenery and is useful for determining vegetation density and detecting plant growth and development. NDVI is calculated as the 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.

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

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):

In this present era of rapid urbanisation, one of the major threats that we are facing is global warming, leading to climatic change and exhibits new challenges for the survival of human beings and wild animals. Another crucial variable in the earth's climate system is land surface temperature. It regulates the rate and timing of plant growth by describing processes such as the exchange of energy and water between the land surface and the atmosphere. Many factors influence land surface temperature, including solar incoming radiation, angle of incidence of solar radiation, surface roughness, moisture content, vegetation extent, 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 (NDVI).

To estimate LST, the different USGS formulas are used to calculate the TOA (Top of Atmospheric) spectral radiance which is converted to brightness temperature conversion, NDVI, proportion of vegetation (P_v), Emissivity (ϵ) and finally LST is calculated.

As a result a map of the Land Surface Temperature will be created and, it should be noted that it is not be equal to the air temperature.

2.7 Digital Elevation Model (DEM):

Cell-based digital elevation models are the most popular digitised data about the geometry of the earth's surface (DEM). This information is used to quantify the land surface's properties. 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 slope of the land must be taken into account in order to reduce building costs, lower the risk of natural disasters such as flooding and landslides, and reduce the negative effects of

proposed development on environmental assets such as soils, plants, and the 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 is a slope map. 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 maps (LULC maps) are useful for addressing environmental issues, supporting planning efforts, and maintaining natural resources such as water. It also refers to man's activity on land and the different purposes to which it is put. 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 can also be used for habitat quality index, land stress index, 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 track changes in water content in water bodies. It's also utilised to tell the difference between water and dry land, and it's ideal for water body mapping. In the visible infrared wavelength region, water bodies have minimal radiation and high absorbability. It's also a remote sensing-derived indicator that estimates the amount of water in the leaves at the canopy level. Water stress can influence the vegetation canopy during drought episodes, affecting plant development in general and perhaps causing crop failure or lower crop yield 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 assessment 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 assessment 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:

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

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

2.11 Habitat Quality Index (HQI):

The HQI is primarily used to assess the habitat quality of the most important protected items in green spaces [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:

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

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 degree of the extinction of the solar beam by dust and haze. In other words, dust, smoke, and pollution in the atmosphere can obstruct sunlight by absorbing or dispersing 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 $0.55 \mu m$ 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 Hierarchy Process and/or Shannon Entropy Method for evaluation of ECC. In this study f-AHP is used for assessment of ECC. The method is described in brief below.

2.13 A Fuzzy Comprehensive Evaluation method:

The f-AHP method is a two-step process used for estimation of ECC. First, the weights of selected parameters are estimated through AHP process and once the weights are estimated the function is created based on evaluation factors to estimate ECC. The AHP is a multi-criterion and multi-objective decision-making method that combines qualitative and quantitative analysis and is applicable to problems which are difficult to fully quantify. The flowchart indicating the forces and parameters which were selected to comprehensively estimate the ECC for Sanjay Gandhi Park are shown in Figure 2.2.

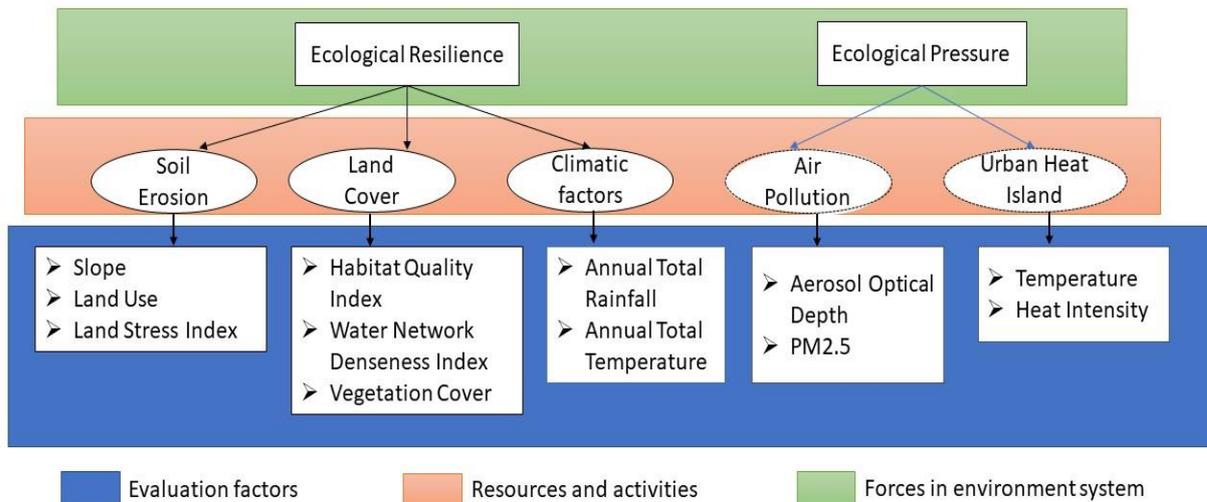


Fig. 2.2: Flowchart representing Evaluation Factors

The hierarchical relations of the evaluation factors for a comprehensive system are constructed through judgement matrix in AHP process. For the judgement matrix, evaluation factors are compared at same level and experts evaluate the importance of these factors according to Saaty’s 9 point scale.

For estimating, the ECC evaluation rating domain was used under a finite group $V = [V_1, V_2, \dots, V_5]$ representing the aggregate of remark grades by the experts considering Saaty’s scale. In this study, 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. Then the membership function was created to describe membership degree of the evaluation factors for estimating ECC. The final matrix representing ECC is shown in equation:

$$ECC = [W_1, W_2, \dots, W_n] \begin{pmatrix} u_1 V_1 & \dots & u_1 V_n \\ u_m V_1 & \dots & u_m V_v \end{pmatrix}$$

In this study, the ECC for the study area was estimated for year 1987, 2000 and 2020 along with estimation of ECC considering buffer zone for all these years as well.

3.0 Assessment of Environmental Carrying Capacity and Environmental Attributes:

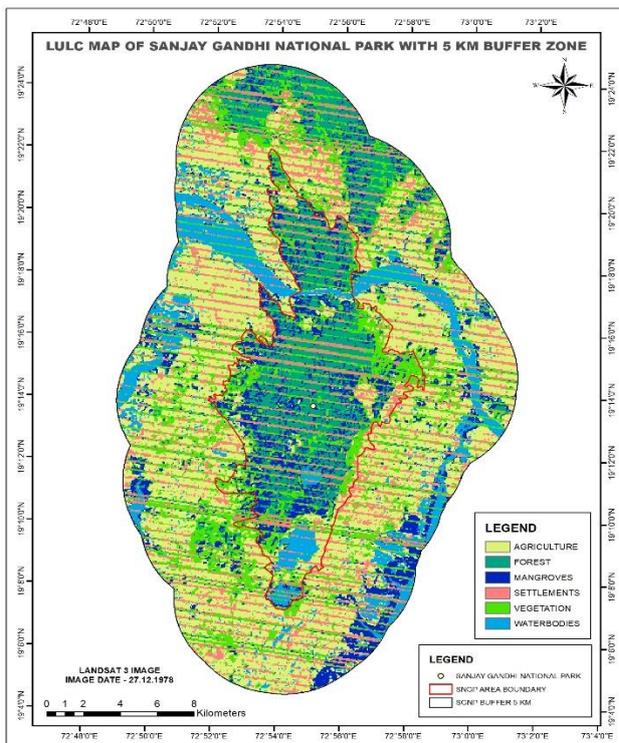
The calculations of the different parameters of the Environmental Carrying Capacity are done with the estimation methods that are discussed above in the methodologies and by considering the data from the Environmental Management Plan for SGNP 2000.

3.1 Calculation of Tourism Carbon Carrying Capacity (TCC)

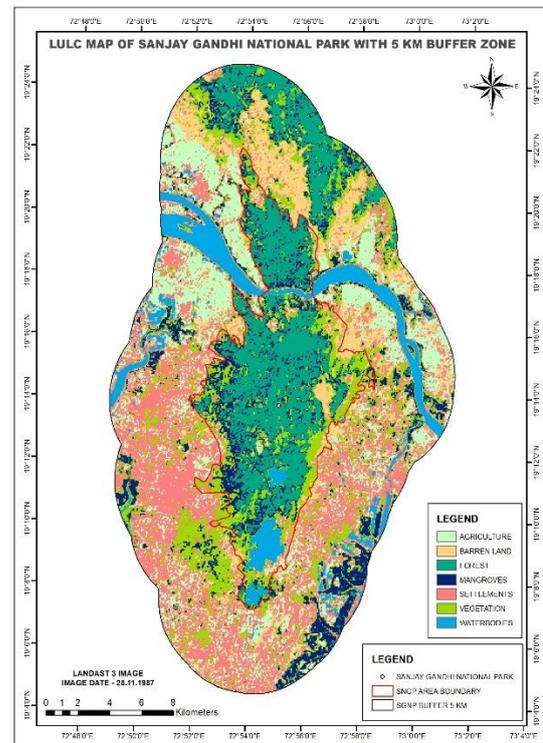
For the calculation of Tourism Carbon Carrying Capacity, area is considered from the LULC maps created by ArcGIS and tourist inflow details are taken from Environmental Management Plan for SGNP 2000. TCC is estimated by using the CO₂ sequestration method and the calculations are done below as follows:

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)

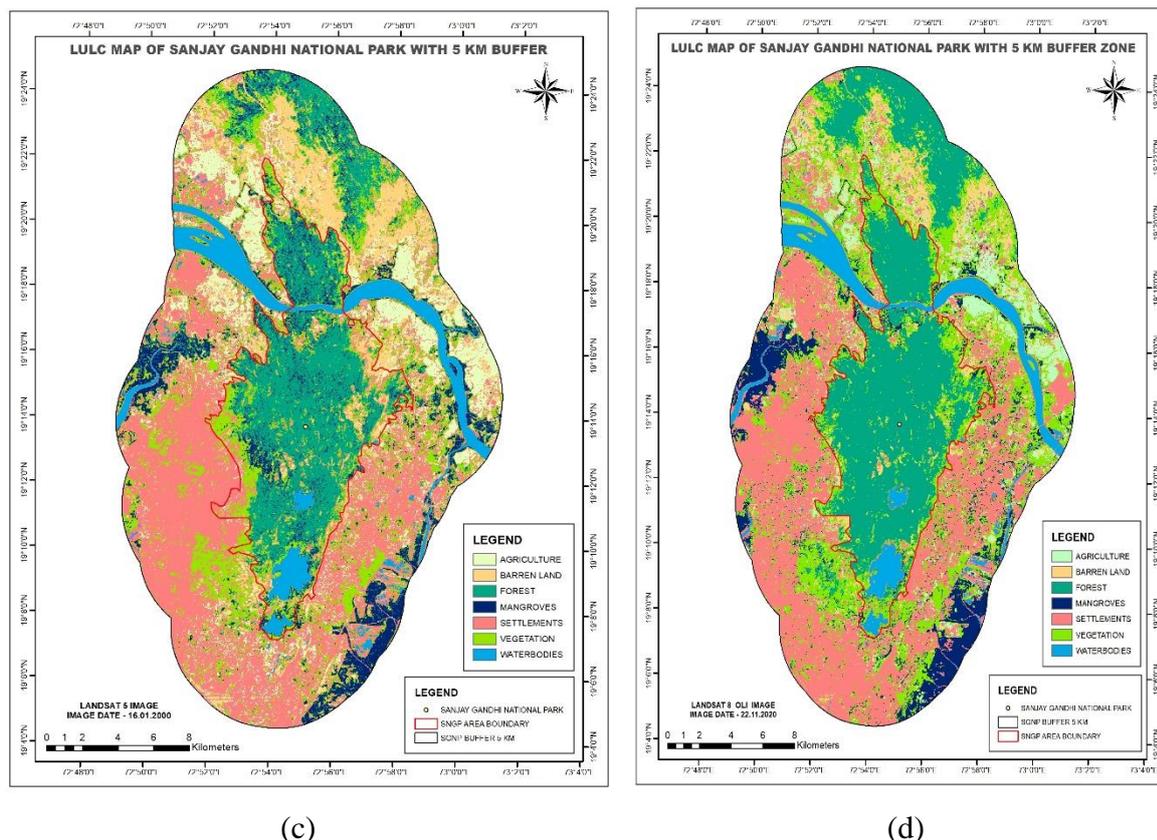


Fig. 3.1(A) Land Use Land Cover (LULC) Map of SGNP with Buffer Zone: (a) 1978, (b) 1987, (c) 2000, (d) 2020

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:

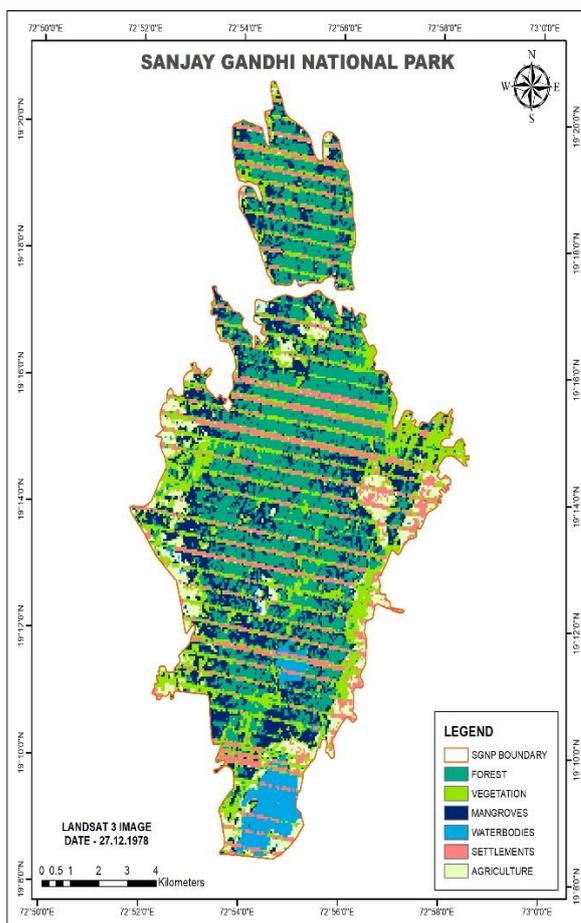
| Category | Year-1978 | Year-1987 | Year-2000 | Year-2020 |
|--------------|--------------|--------------|--------------|--------------|
| | Area (Sq.km) | Area (Sq.km) | Area (Sq.km) | Area (Sq.km) |
| Forest | 67.7 | 88.70 | 96.93 | 127.23 |
| Vegetation | 110.59 | 92.30 | 92.77 | 124.57 |
| Mangroves | 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 will be beneficial for the wildlife ecosystem. Mangroves and water body areas are however

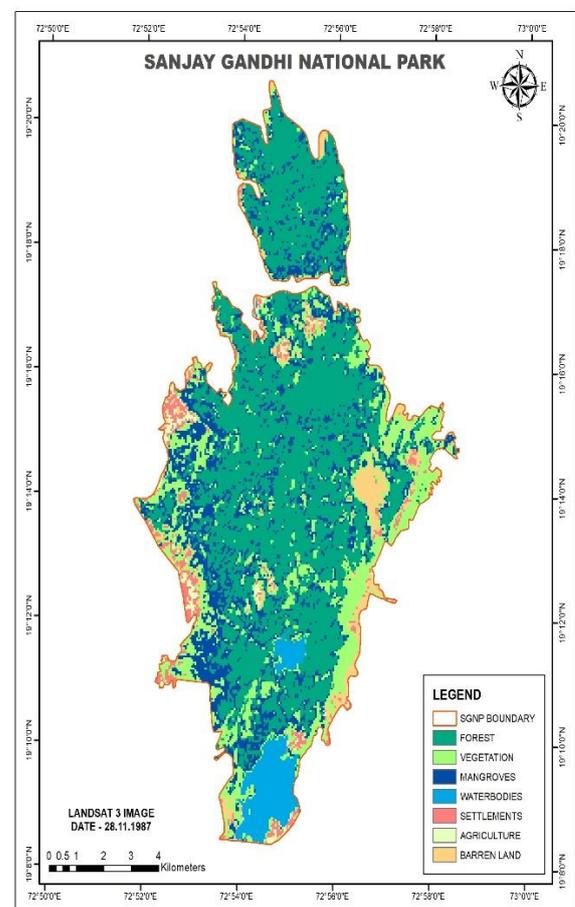
decreasing year by year and indicates a threat to the balance of the environment. Human settlements are also increasing year by year till the year 2000, while showing reduction after that. The remote sensing data should be ground verified to understand the actual status of human settlements in the SGNP. In general terms, encroachments in the ecologically sensitive area should 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)

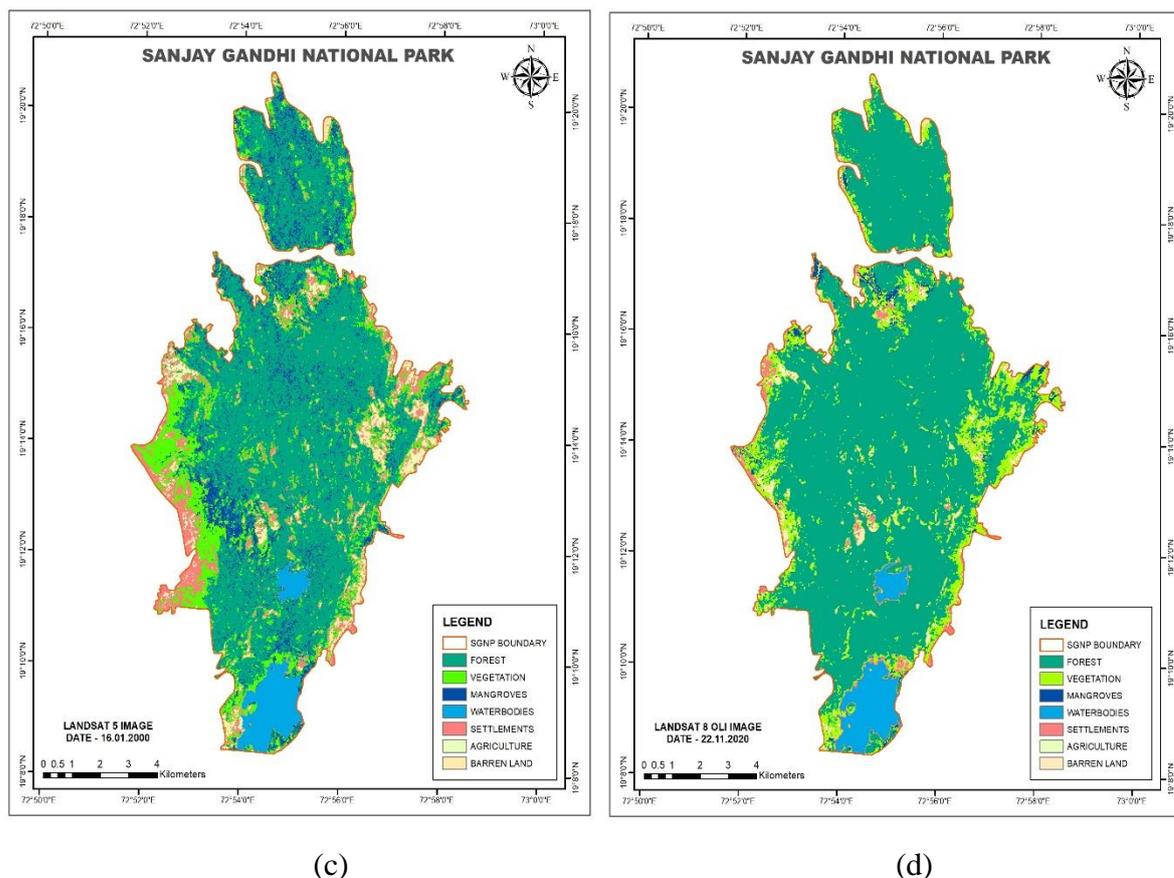


Fig. 3.1(B) Land Use Land Cover (LULC) Map of SGNP: (a) 1978, (b) 1987, (c) 2000, (d) 2020

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): Area of SGNP with Buffer: ArcGIS Maps

| 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 CO₂ 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 |
| CO₂ Sequestration (Carbon Absorbed * 3.67) | 4073235 | 5262548 | 5371718 | 6444763 |

| | | | | |
|---|---------------|---------------|---------------|---------------|
| Tourism Carrying Capacity (CO ₂ Sequestration * r) | 130343 | 168401 | 171894 | 206232 |
|---|---------------|---------------|---------------|---------------|

Sample Calculation: (For Year 2020)

Area of Forest (Evergreen) = 4515 ha

Standing Biomass = 485 t/ha [4]

Biomass = Area * Standing Biomass [3]

$$= 4515 * 485$$

$$= 2190073 \text{ tonnes}$$

Total biomass = 3512132 tonnes

Carbon Absorbed = Total biomass * 0.5 [3]

$$= 3512132 * 0.5 = 1756066 \text{ tonnes}$$

CO₂ Sequestration = Carbon Absorbed * 3.67 [3]

$$= 1756066 * 3.67 = 6444763 \text{ tonnes}$$

TCC = CO₂ Sequestration * r [3]

$$= 6444763 * 0.032$$

$$= 206232 \text{ footfall}$$

The total footfall value observed for the study from Environmental Management Plan of SGNP 2000 was 1466359 while the calculated footfall values by CO₂ 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 |

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

$$\begin{aligned} \text{Amount of water Consumed} &= 18 + 68 = 86 \text{ MLD} \\ &= 86000 \text{ m}^3/\text{day} \\ &= 31390000 \text{ m}^3/\text{year} \end{aligned}$$

$$\text{Total Available Water Resources (Year)} = (42000000 + 10430000) = 52430000 \text{ m}^3$$

Therefore,

$$\begin{aligned} UR_{\text{Available Water Resources}} &= \frac{\text{Amount of Water Consumed}}{\text{Total Available Water Resources}} \\ &= (31390000 / 52430000) * 100 \\ &= 59.87 \% \end{aligned}$$

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 the following 3 areas are selected and Environmental Management Plan for SGNP 2000 provides noise level ranges of 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 and CPCB Noise standards for comparison.

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

| Location | Season | Noise Levels dB (A) | | |
|---------------|--------------|---------------------|------------|---------|
| | | Day Time | Night Time | Average |
| Tulsi lake | Winter | 35-36 | 30-36 | 36 |
| | Summer | 39-47.3 | 38-39.5 | 43 |
| | Post Monsoon | 41-56 | 39-47 | 47 |
| Yeur Village | Winter | 33-56 | 34-47 | 41 |
| | Summer | 39-58 | 38-41 | 44 |
| | Post Monsoon | 40-58 | 39-50 | 50 |
| SGNP Entrance | Winter | 35-61 | 35-46 | 47 |
| | Summer | 39.5-65.3 | 37-49.5 | 51 |
| | Post Monsoon | 40-60 | 38-53 | 49 |

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 baseline seasonal noise level data in SGNP shows that it is within the limit in some regions while in some regions it exceeds. 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, the average values of noise levels are within the limit except for the SGNP entrance gate due to high traffic flows and other human activities.

While the current NCC assessment is restricted on the basis of standards defined as per human thresholds, it is important that impacts on faunal biodiversity is understood in detail for tailored

understanding of NCC. Similarly impact of illumination should also be explored in detail in order to determine its thresholds.

3.4 Calculation of Air Carrying Capacity (ACC):

The values of air pollutants such as SO₂, NO₂, SPM and RSPM measured in the SGNP environment, provided in Environmental management plan for SGNP 2000 are considered and compared with NAAQS values of each pollutant to harness the Utilization ratio for AECC calculation and are estimated as follows:

$$UR_{SO_2} = \frac{7.3}{15} * 100 = 48.66 \%$$

$$UR_{NO_2} = \frac{32.7}{30} * 100 = 124 \%$$

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

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

The utilisation 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, the calculated value is exceeding the reference value for the air pollutants considered in our study except for SO₂. It shows that air pollutants like NO₂, SPM and RSPM are polluting which are mainly due to vehicular emissions and particulate matter due to which the SGNP environment is getting affected very badly.

The calculations done above are based on the selected fundamental methodologies of carrying capacity assessment. But estimation of ECC is critical and should be done precisely as far as possible, advanced tools such as Remote sensing and GIS are being used to assess the environmental attributes like NDVI, LST, LULC, NDWI, LSI and HQI, which are analysed for the SGNP and the buffer area and is explained further in trailing sections.

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 studied well for the ECC assessment. The study objectives also extend this approach to the core zone in the near future. The different parameters analysed are explained below:

3.5.1 Normalized Difference Vegetation Index (NDVI) of SGNP:

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

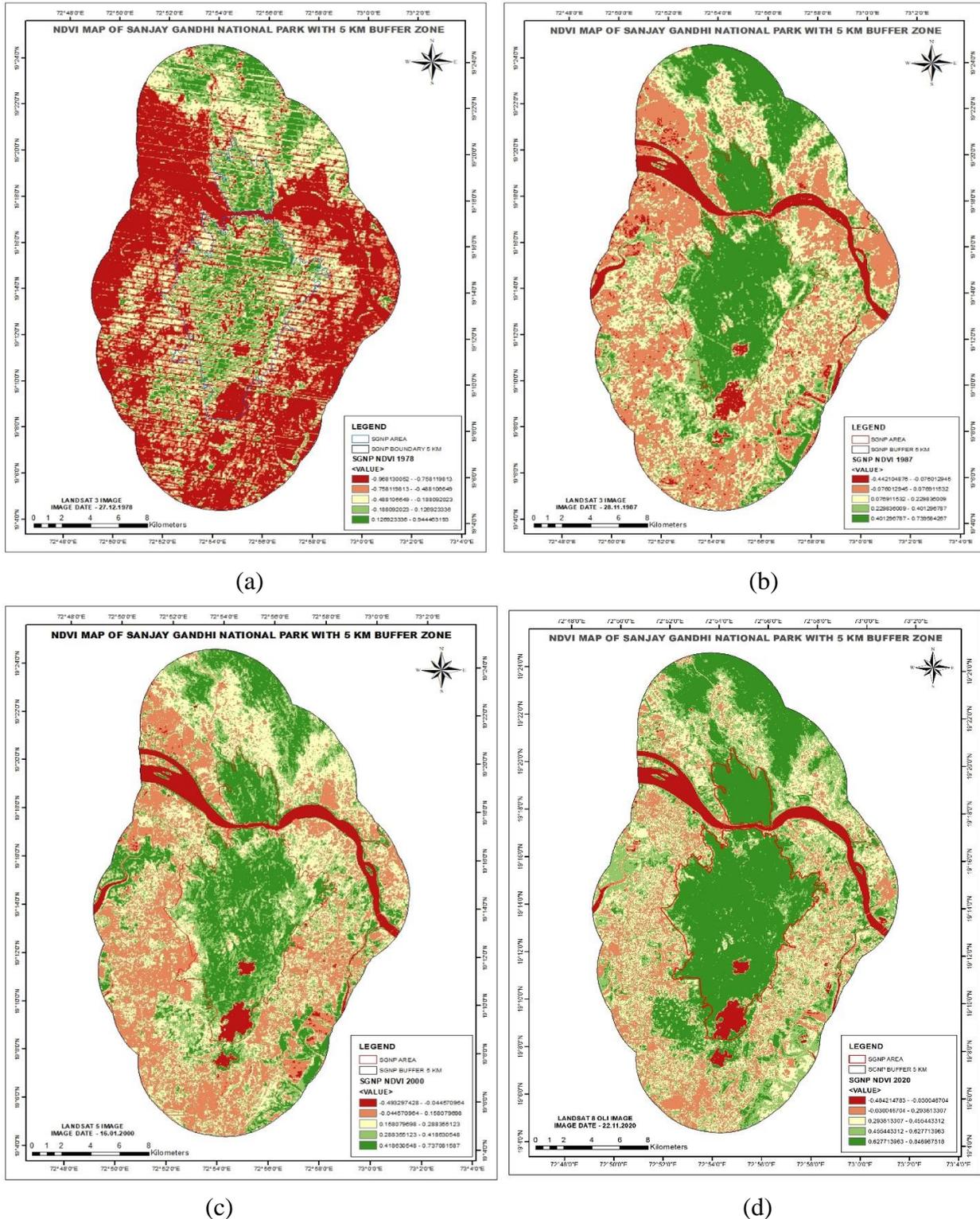


Fig. 3.2 Normalized Difference Vegetation Index (NDVI) of SGNP: (a) 1978, (b) 1987, (c) 2000, (d) 2020

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 it's carrying capacity.

3.5.2 Normalized Difference Water Index (NDWI) of SGNP:

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

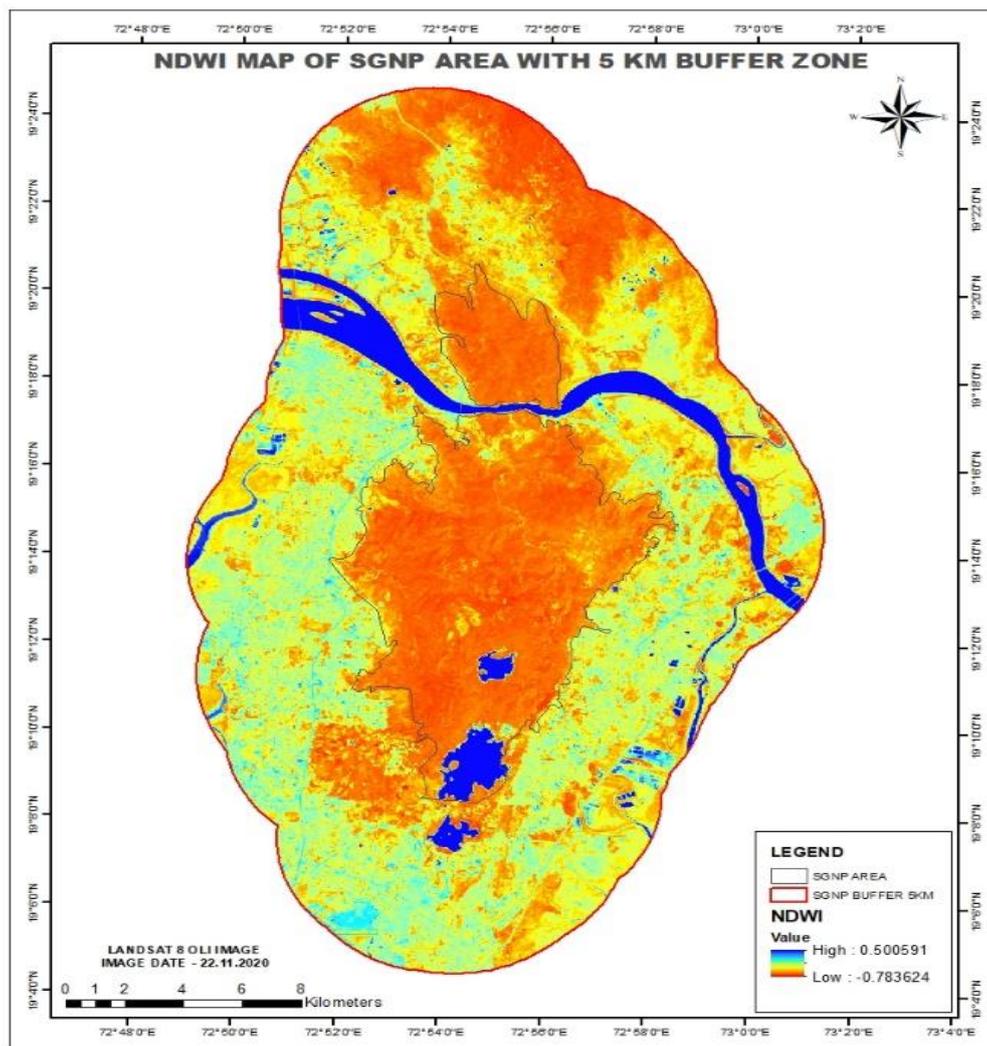


Fig. 3.3 Normalized Difference Water Index (NDWI) Map of SGNP

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:

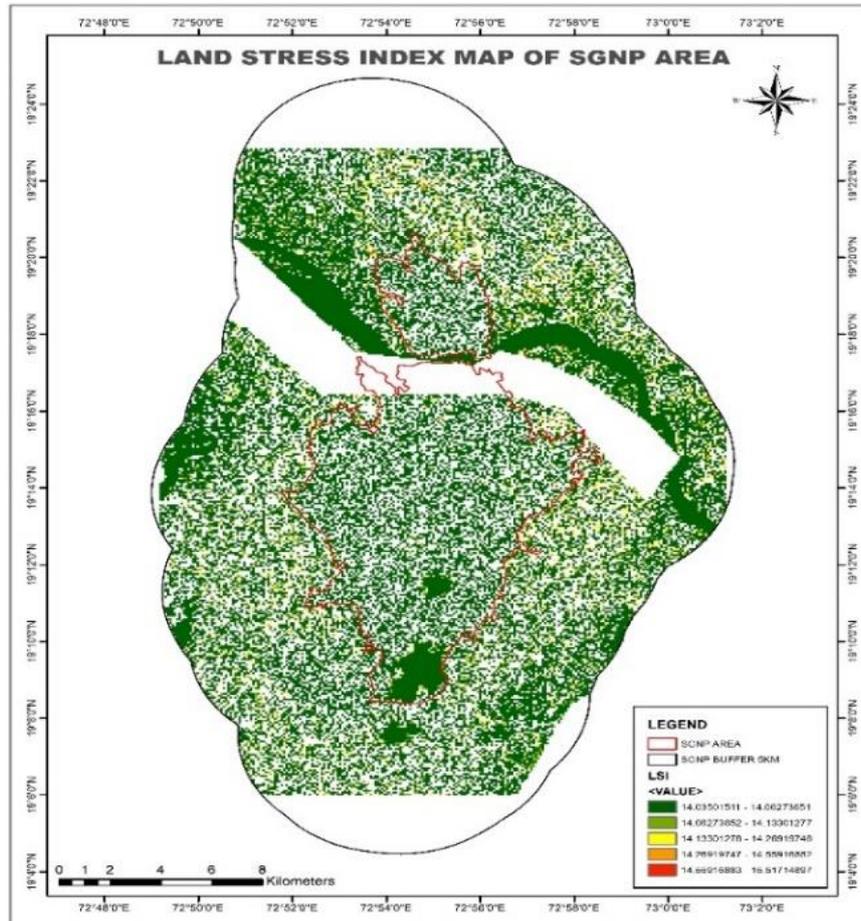


Fig. 3.4 Land Stress Index (LSI) Map of SGNP

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, less chances of erodibility. On ground verification of the remotely sensed data is necessary in this case along with secondary literature.

3.5.4 Slope Map of SGNP:

The slope map of the study area is shown below:

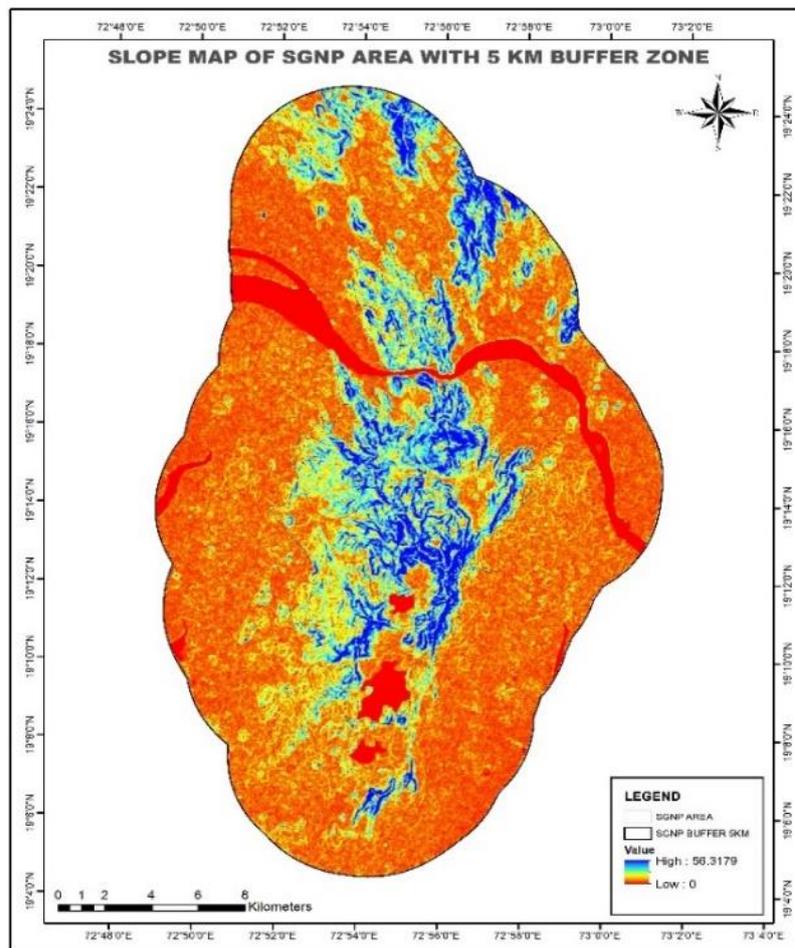


Fig. 3.5 Slope Map of SGNP

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°C which has increased to 24.34°C in 2020. This increase needs attention and should be monitored constantly. The LST map of the study area for year 2000 and 2020 is shown below:

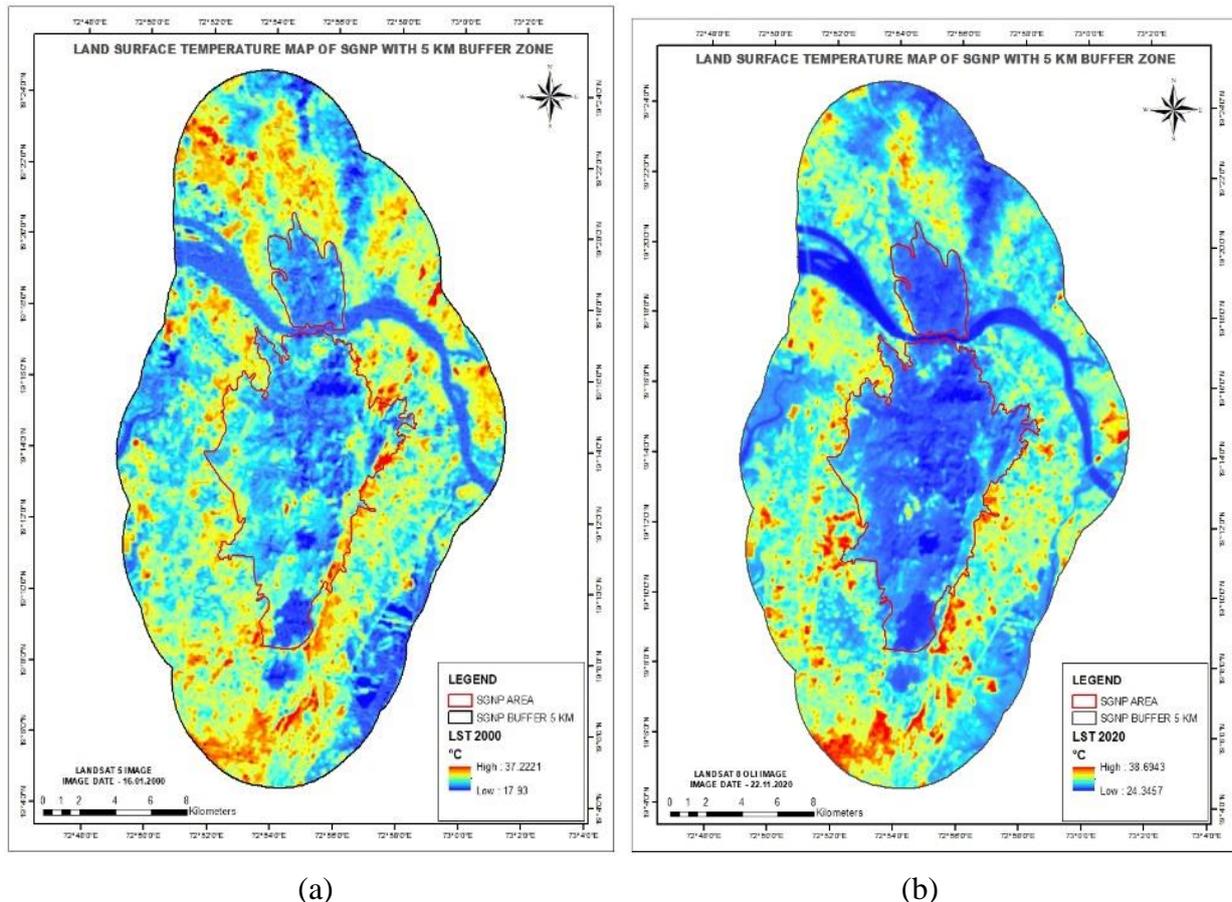


Fig. 3.6 Land Surface Temperature (LST) Map of SGNP: (a) 2000, (b) 2020

3.5.6 Habitat Quality Index (HQI) of SGNP:

The Habitat Quality Index (HQI) is primarily used to assess the adequacy of the habitat quality of the most important protected items in natural habitats. 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. On ground validation of the remotely sensed data is necessary which shall be attempted during the next phase of the project.

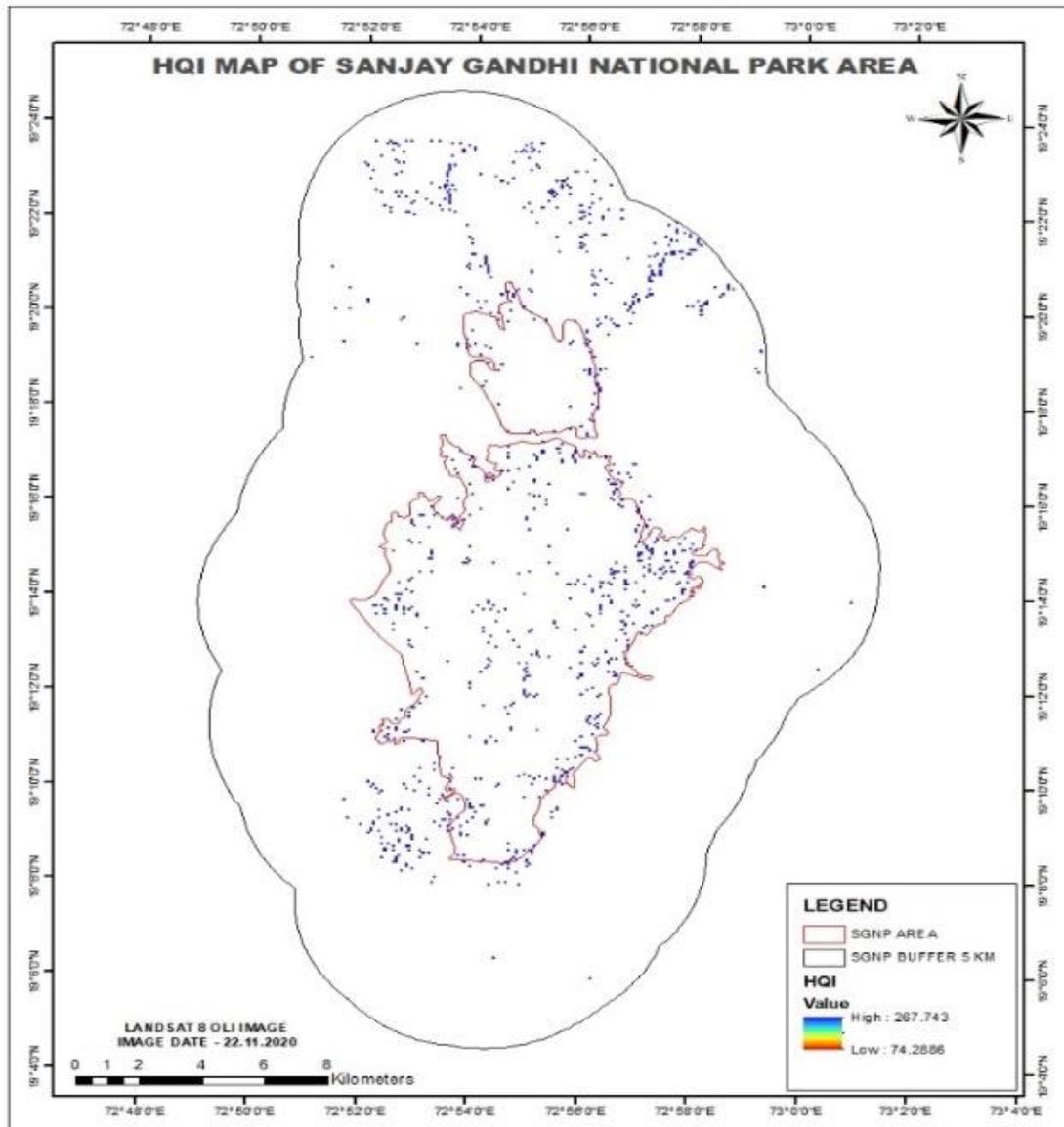


Fig. 3.7 Habitat Quality Index (HQI) Map of SGNP

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} (µg/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 and air pollution due to poor meteorological conditions. The map showing the details of aerosol optical depth and PM_{2.5} is shown below. Detailed analysis of AOD and PM_{2.5} with better time resolution and continued monitoring is necessary to conclude this. These parameters form a crucial factor layer in the analytic hierarchy process.

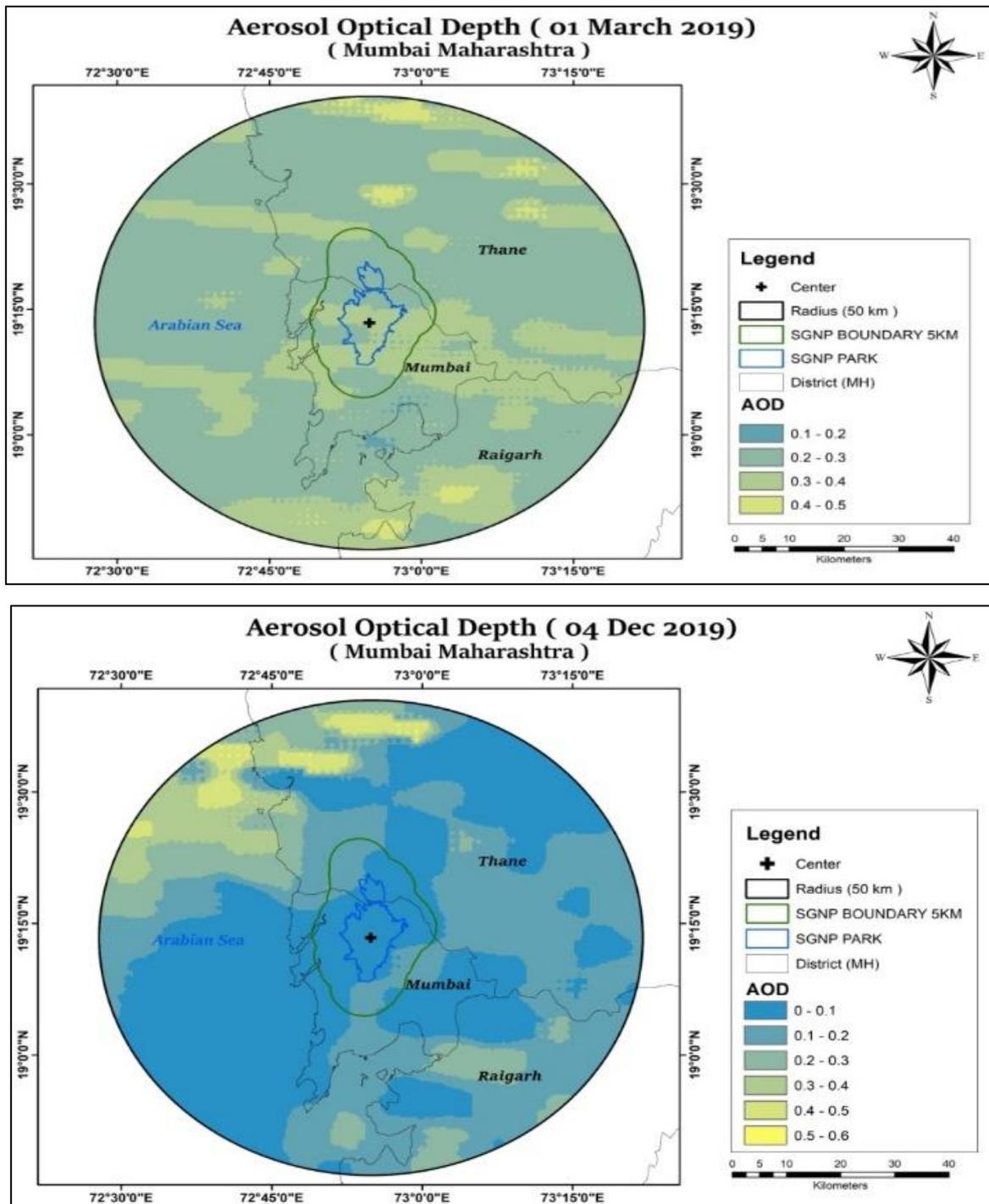


Fig. 3.8 Aerosol Optical Depth Map of SGNP

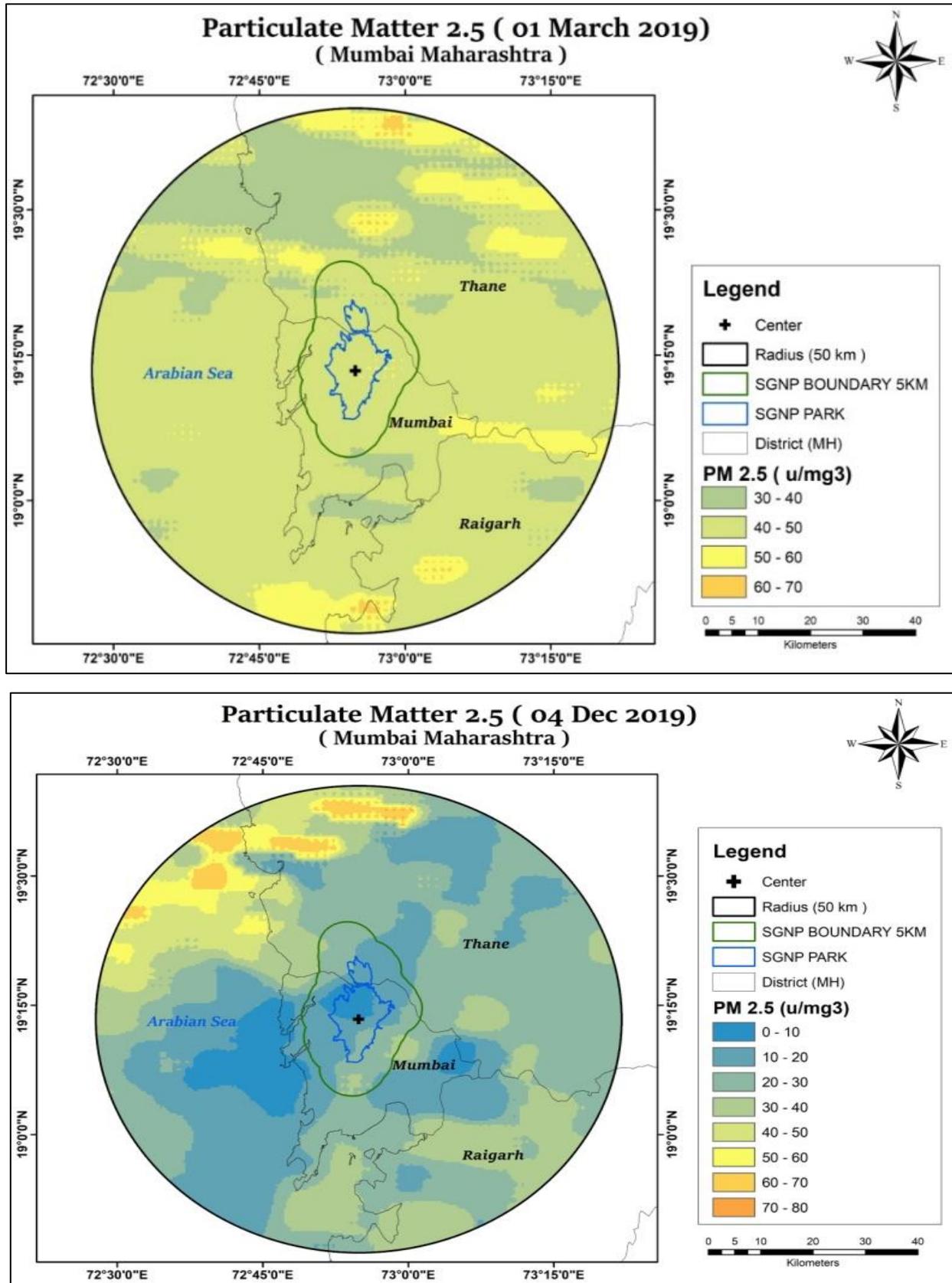


Fig. 3.9 Particulate Matter PM_{2.5} Map of SGNP

From the analysis of above environmental attributes, it has been seen that there are certain parameters which suggest that there is a breach of environmental carrying capacity. Parameters such as land use, air pollution, AOD, PM_{2.5}, Noise, Tourism and so on indicate that the park might be under tremendous environmental pressure while other factors such as biomass, forest, NDVI, NDWI etc indicate that sufficient environmental carrying capacity is maintained. Hence this preliminary analysis is substantiated with more data and further assessment of environmental carrying capacity using f-AHP is done in this study.

3.6 Assessment of Environmental Carrying Capacity (ECC) using AHP:

Based on described methodology, the ECC was estimated for different years and the weights obtained using AHP process for evaluation factors is shown in Table 3.11.

Table 3.11: Subjective Weights based on Analytical Hierarchy Process Method:

| Evaluation factors | Factor type | Weight |
|-------------------------------|--------------------|---------------|
| Slope | Negative | 0.191 |
| Land Use | Negative | 0.084 |
| Land Stress Index (LSI) | Negative | 0.19 |
| Habitat Quality Index | Positive | 0.016 |
| Water Network Denseness Index | Positive | 0.066 |
| Vegetation Cover | Positive | 0.016 |
| Annual Total Rainfall | Negative | 0.034 |
| Annual Total Temperature | Negative | 0.05 |
| AOD | Negative | 0.097 |
| PM 2.5 | Negative | 0.103 |
| Temperature | Negative | 0.057 |
| Heat Intensity | Negative | 0.097 |

The fuzzy matrix obtained for estimating ECC is shown in Table 3.12 for SGNP without buffer.

Table 3.12: Fuzzy Matrix for year 2020 for SGNP without buffer:

| Evaluation factors | Remark Grades | | | | |
|-------------------------------|----------------------------|-----------------------|----------------------------|------------------------|-----------------------------|
| | Very Low (V ₁) | Low (V ₂) | Moderate (V ₃) | High (V ₄) | Very High (V ₅) |
| Slope | 0.3427 | 0.6572 | -1.4469 | FALSE | 0 |
| Land Use (Sq. Km) | 0 | 0 | 0 | 0 | 0 |
| Land Stress Index (LSI) | 0.21875 | 0.7812 | -0.7241 | FALSE | 0 |
| Habitat Quality Index | FALSE | FALSE | 0.6379 | 0.3620 | 1 |
| Water Network Denseness Index | 0 | 0 | 0 | 0 | 1 |
| Vegetation Cover (Sq. Km) | FALSE | FALSE | FALSE | 0.3863 | 1 |
| Annual Total Rainfall (mm) | 0 | 0.7528 | 0.2471 | FALSE | 0 |
| Annual Total Temperature | 0 | 0.3571 | 0.6428 | FALSE | 0 |
| AOD | 0 | 0 | 2.4 | 0.6363 | 0.3636 |
| PM 2.5 | 0 | 0 | 0.3636 | 0.6363 | 0 |
| Temperature (°C) | 0 | 0.6995 | 0.3004 | FALSE | 0 |
| Heat Intensity (°C) | 0 | 0.1428 | 0.8571 | FALSE | 0 |

The fuzzy matrix was constructed for different years i.e. 1987, 2000 and 2020 and then it was multiplied with weights to estimate the ECC. The ECC thus found was for SGNP with and without buffer under different grades. The maximum value of ECC corresponding to grade was selected as final ECC for SGNP and SGNP buffer and corresponding ECC status was estimated.

The estimation of ECC for different years in the study are with and without buffer is shown in Table 3.13.

Table 3.13: Environmental Carrying Capacity (ECC) values for SGNP:

| Year | Environmental Carrying Capacity | |
|------|---------------------------------|---|
| | Sanjay Gandhi National Park | Sanjay Gandhi National Park with buffer |
| 1987 | 1.497 (Moderate) | 0.519 (Moderate) |

| | | |
|------|----------------------|----------------|
| 2000 | 0.2334 (very low) | 0.381 (Low) |
| 2020 | 0.25 (Low) | 0.371 (Low) |

The values in Table 3.12, are maximum of the values obtained across V₁ to V₅ grade and corresponding grade in which they were lying is shown in brackets below. From, Table 3.13 it can be inferred that SGNP area was under moderate carrying capacity in year 1987 and after that due to air pollution and urban heat island effect the ECC of the region started deteriorating and in year 2000 it reached to very low stage. After 20 years, the inside of SGNP has improved but still the ECC remains low which is a matter of concern. Therefore, the efforts are required to maintain the area in such a way that it can be taken to its state of year 1987 when it has moderate ECC.

4.0 Summary:

Eco-Sensitive Zones (ESZs) or Ecologically Fragile Places (EFAs) are areas around Protected Areas, National Parks, and Wildlife Sanctuaries in India that have been recognised by the Ministry of Environment, Forests, and Climate Change (MoEFCC), Government of India. Declaring ESZs has the goal of creating "shock absorbers" for protected areas by regulating and supervising activities in and around them. 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.

Ecosystems and populations have a limited capacity to cope with environmental stress; stress above a certain threshold may be detrimental for the ecosystem. Hence carrying capacity assessment, which is a tool to determine "the growth limits that an area can accommodate without violating environmental capacity goals", are a need of the hour to protect such ESZs.

Owing to the limited literature, data availability, selected methodologies, our calculations and findings currently show that some of the environmental attributes are within the permissible limits of carrying capacity while some have exhausted the limits. The utilization ratio of available water resources in SGNP is 59.87%, which is less than the reference value of 100%. However, as indicated in the assessment section, the CC should be evaluated consistently in order to understand the changes in UR and plan for restoration, if needed.

The total calculated footfall, in terms of tourists, shows that it is in a critical stage and has exceeded the maximum footfall possible when compared with the carbon sequestration potential of the area and hence that can affect the wildlife and its carrying capacity. The average values of noise levels are within the limit except for the SGNP entrance gate due to high traffic flows and other human activities, and it should be controlled by suitable measures. The utilization ratio calculations for air pollutants show some of the air pollutants are already beyond the safe limits and it is high time to consider this serious issue. With appropriate air pollution and noise control management measures installed, the values can be maintained within limits without affecting the tourism population and the flora and fauna of the park. Assessment in reference to the impact to faunal diversity of the park is also to be attempted during the detailed planned study as indicated earlier.

The comparison of NDVI values indicates that the vegetation cover of SGNP 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, which must be beneficial for the wildlife and overall ecosystem. Mangroves and water body areas, within the SGNP and buffer area, analysed through remote sensing data, are decreasing year by year. Human settlements are increasing year by year till 2000 in the SGNP area, while the increase is noted till date in the area including buffer, indicating a threat to the balance of the environment. This indicates that construction in the area should be avoided, as it might disturb the balance of ecological systems in the area. The LST maps of SGNP displays that surface temperature increased in 2020 when compared to 2000. This increase needs attention and should be continuously monitored. Preliminary analysis of SGNP indicates limited land stress which should be maintained as is for ecological balance to be maintained. The mean values of AOD and PM_{2.5} show variations, and the maximum values of AOD and PM_{2.5} estimated in SGNP in 2019 indicate higher anthropogenic activities and air pollution, which is also confirmed by the ground data given in the literature.

The above environmental attributes are indicating that the eco sensitive zone under consideration is at a critical stage and in order to make a positive intervention and to restore the qualities of the eco-sensitive zone the assessment of carrying capacity is unavoidable and the same is evaluated in this report. Parameters like air and noise might be clearly indicating a pressurized state, however, improvement in vegetation is a positive sign. In order to clearly understand the carrying capacity of the SGNP, these critical environmental attributes are weighed scientifically and f-AHP is used to derive a meaningful conclusion in relation to environmental carrying capacity. The above parameters and the values ascertained using remote sensing and secondary literature forms the baseline scenario and is used for above advanced tool to estimate the overall environmental carrying capacity of the eco-sensitive zone.

The preliminary conclusion based on secondary data analysis concludes the following points:

1. Construction within the premises of the SGNP should be discouraged as it will affect the fragile ecosystem of the area. This will also put pressure on other environmental attributes such as water, air and noise which will affect the overall environmental carrying capacity.
2. Assessment of NCC will need a detailed analysis with biodiversity centric focus, given the impact of species present in the area can be severely affected. This aspect is to be explored in depth and a long term study is needed in this regards.

3. Suitable measures to curb the impacts of air and noise pollution in the area should be employed at the earliest to preserve the floral and faunal biodiversity.
4. The slope factors of the area show a reduced stress on land which should be maintained by avoiding construction activities in the area.

Further evaluation of the ECC for SGNP using f-AHP and considering the ecological parameters selected on a time scale shows that the ecological pressure is increasing in the area in terms of pollution and increasing temperatures. Hence seeing the temporal variation for ECC for SGNP, the following conclusions are made:

- 1) The ecological resilience factors like land cover which can be improved should be done on priority.
- 2) The ecological pressure inducing factors such as air pollution needs to be minimized by controlling the particulate matter.

To summarise, the ECC of the SGNP has deteriorated considerably, and efforts should be made ahead of time to ensure that the present CC is protected and improved upon.

5.0 References:

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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 be 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