Central Zoo Authority
केन्द्रीय चिड़ियाघर प्राधिकरण

Nature Protects if She is Protected

TERI
THE ENERGY AND RESOURCES INSTITUTE
Creating Innovative Solutions for a Sustainable Future

Economic Valuation of Ecosystem Services

National Zoological Park, New Delhi

Help Conserve Wildlife
National Zoological Park
New Delhi

2020

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सूचना एवं प्रसारण और
भारी उद्योग एवं लोक उद्यम
भारत सरकार

स्वच्छ भारत
एक कदम स्वच्छता की ओर

सत्यमेव जयते

MINISTER
ENVIRONMENT, FOREST & CLIMATE CHANGE,
INFORMATION & BROADCASTING AND
HEAVY INDUSTRIES & PUBLIC ENTERPRISES
GOVERNMENT OF INDIA

प्रकाश जावडेकर
Prakash Javadekar

FOREWORD

At the moment, when the whole world is coping with the effects of CoVID- 19 virus, we are now looking back at nature to provide solutions to mitigate its impacts. Nature and its ecosystem services have been taken for granted by humans for long. The current state has well highlighted the importance of a natural ecosystem, its services and relation to human wellbeing. It is of utmost importance to protect and conserve these natural habitats of India to ensure smooth flow of the ecosystem services they generate. Currently, when our country is moving rapidly on the path of development, it is our combined responsibility to identify, understand and value the many ecosystem services provided by the natural ecosystems to reduce pressures on them.

It is heartening to note that CZA along with TERI has come up with this informative report in which the potential of zoological parks has been appropriately highlighted as an important habitat in providing numerous ecosystem services which improve the local environment. I am also informed that this study is 'first of its kind' for habitats such as zoological parks in India. I am sure that this report shall foster scientific evidence and influence decisions for efficient management of zoological parks in the country.

I am sure this report will be of great relevance to the spectrum of stakeholders such as policy makers, academicians, administrators and community based organizations. I congratulate CZA and TERI and look forward to many more such achievements by them in future.

Date: 01.10.2020

(Prakash Javadekar)

।। प्लास्टिक नहीं, कपड़ा सही ।।

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Central Zoo Authority
केन्द्रीय चिड़ियाघर प्राधिकरण

Dr. S. P. Yadav
Member Secretary

FOREWORD

I am pleased to note that the Central Zoo Authority (CZA), in association with The Energy and Resources Institute (TERI), has developed a Report on the "Economic Valuation of Ecosystem Services of National Zoological Park, New Delhi". Zoological Parks in India are long-neglected habitats and their potential to provide ecosystem services is not yet studied. It is heartening to know that this study is first-of-its-kind which endeavours towards estimating the economic value of ecosystem services for lesser-known habitats such as Zoological Parks. Zoological Parks are unique ecosystems that provide numerous services of local and national significance and this makes it necessary to realize the potential of these ecosystem services towards societal and overall human development.

The Report, besides proposing a powerful methodology for baseline assessment of the important ecosystem services provided by the Zoological Park, also marks an important step by the CZA and TERI in making nature's economic value visible. The importance of Zoological Park in providing services such as carbon sequestration & storage, biodiversity conservation to free-ranging flora & fauna, employment generation, recreation & cultural services, and education & research service has been well highlighted through this Report as per the pilot study conducted at National Zoological Park, New Delhi.

I am confident that this report will demonstrate and realize the benefits of numerous Zoological Parks established in India. The findings of this Report will create the basis for various academic and research institutions for undertaking future studies on ecosystem valuation.

(Dr. S. P. Yadav)

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Preface

Dr. Ajay Mathur

Director General

The Energy and Resources Institute (TERI)

Today, the economic valuation of ecosystem services is recognized as an important way of valuing the many benefits that nature provides for human wellbeing. It is a powerful tool for decision making as it helps to incorporate the ecological value into our developmental policies and decisions making which could facilitate more effective planning and management. Humans have always considered ecosystem services as a gift from nature without realizing the fact that they need to be maintained regularly to ensure their smooth flow. The maintenance of the service surely incurs a huge cost and hence these services may not be taken as granted to be a gift.

Zoological Parks in India are unique ecosystems that provide several services of local and national significance. The National Zoological Park in New Delhi is one such unique park spread across an area 176 acre and based around the cultural landscape of the Old Fort. The campus of Delhi zoo not just consists of the infrastructure of animal enclosures, hospitals, offices, etc. but also consists of natural vegetation and wetlands which prove to be an important habitat for the local free-ranging flora and fauna, and thus provides services such as carbon sequestration, biodiversity conservation, air purification, water purification, education and research, recreational and cultural, employment generation, etc.

TERI presents the results of 'first of its kind' study Economic valuation of ecosystem services of National Zoological Park in Delhi with a robust and refined methodology. The annual value of key ecosystem services comprising of use and non-use values such as carbon storage and sequestration, employment generation, recreation, education and research, biodiversity conservation, the surrogate value of land has been evaluated in this study. The total annual economic value of the ecosystem services (biodiversity conservation, employment generation, carbon sequestration, education, and research, recreational and cultural) is estimated to be INR 422.76 crore (2019-20). The total value of the one-time cost of services such as carbon storage and land value provided by the zoo is estimated to be INR 55,209.45 crore. This study highlights the importance of habitats such as zoos to human wellbeing and the need for replication across India.

I extend my heartfelt gratitude to Dr. SP Yadav, Member Secretary, Central Zoo Authority, Government of India, and Shri Ramesh Kumar Pandey, Director, National Zoological Park, New Delhi. This report has been made possible with the dedicated efforts of Dr. J. V. Sharma, Director, and Mr. Yatish Lele, Associate Fellow along with the entire Land Resources Division team of TERI. I express my appreciation for their hard work and dedication in completing the task in a time-bound manner. Presenting this report on "Economic valuation of the ecosystem services of National Zoological Park, New Delhi" is a matter of pride and gives immense satisfaction to the organization.

(Dr. Ajay Mathur)

Executive Summary

Economic valuation of ecosystem services provides a way of valuing the many benefits that nature provides and helps 'make the contribution of nature to livelihoods and economies visible'. Ecosystem services are the direct and indirect contributions of ecosystems to humankind's well-being which support our survival and quality of life. The valuation of ecosystem services provides a powerful tool to enable rational decision-making and eases the incorporation of ecological values into economic policies. This can facilitate more effective planning and management. There is a need for valuation because the environment offers many services that, in essence, are free and do not have any traditional 'market values' attached. Thus, it is necessary to realize the value of ecosystem services to understand their contribution to societal and overall human development.

Zoological parks in India are unique ecosystems that provide numerous services of local and national significance. Apart from their primary function in education and research, many zoos, serve as natural habitats for free-ranging animals. Moreover, such parks are sources of carbon sequestration, air purification, water purification, noise attenuation, etc. The National Zoological Park, New Delhi, is one such park spread across 176 acres, overlooking the cultural landscape of the Old Fort. The zoo is home to several species of mammals, birds, and reptiles from around the world. As of 2018, there are 40 species of endangered animals under Schedule I and II categories; 35 species of animals under Schedule III and IV categories; and 29 species of exotic animals as specified under the Indian Wildlife (Protection) Act, 1972. Apart from enclosures for wild animals and administrative buildings, the zoo sustains a natural environment in its campus which provides habitat for several free-ranging floral and faunal species.

In this context, the Central Zoo Authority (CZA) had requested The Energy and Resources Institute (TERI) to conduct a study titled 'Economic valuation of ecosystem services of National Zoological Park, New Delhi' to understand the annual value of key ecosystem services such as biodiversity conservation, carbon storage, and sequestration, employment generation, recreational and cultural, education and research. The results of the study are summarized as follow:

The total annual economic value of ecosystem services

S. No.	Ecosystem service	Type of service	Valuation technique	Total value (INR) (crore/ year)
1.	Biodiversity conservation	Non-use value	Contingent valuation	27.33
2.	Employment generation	Direct-use value	Market price	32.19
3.	Education and research	Indirect-use value	Market price	37.6
4.	Carbon sequestration	Indirect-use value	Market price	1.31

S. No.	Ecosystem service	Type of service	Valuation technique	Total value (INR) (crore/ year)
5.	Recreational and cultural	Indirect-use value	Individual travel cost method	324.33
				422.76

The one-time cost of ecosystem services and value of land

S. No.	Ecosystem service	Type of service	Valuation technique	Total value (INR/crore)
1.	Carbon storage	Indirect-use value	Market price	17.15
2.	Surrogate value of land	Non-use value	Hedonic price method and opportunity cost	25
3.	The land value of the Delhi zoo	Non-use value	Market price (benefit transfer)	55,167.30
				55,209.45

The total annual economic value of the ecosystem services provided by the National Zoological Park for 2019–20 is estimated to be **INR 422.76 crore**. The total value of the one-time cost of services and land value provided by the zoo is estimated to be **INR 55,209.45 crore.** Almost 77% of the contribution comes from the recreational and cultural service which indicates the significance of this service to the zoo. Education and research, the next most important service, contributes 9% to the total economic value. Irrespective of the contributions, every service is important as it contributes towards the improvement of the local environment. The benefits of the zoo are not only restricted to its visitors but also reach Delhi's citizens. Hence, it is necessary to ensure the proper maintenance of the zoo to improve its services.

The study is based on the data collected for the year 2019-20 and hence should be considered as the baseline year. In case of need to use the valuation figure in the future, the values should be multiplied with the annual inflation rate and the number of years by using the compounding formula to assign the value for that particular year.

This study is 'first of its kind' for habitats such as zoological parks in India. Such studies must be replicated across India to understand the value of zoos. The results of the total economic valuation of the National Zoological Park provide conservative estimates based on the primary and secondary data collected during the study. Nevertheless, the study gives a powerful baseline assessment of the important ecosystem services provided by the zoo. The way forward of this study is to have an in-depth valuation of those ecosystem services which are not being valued due to limited time and resource.

Introduction

Valuation of Ecosystem Services

Ecosystem services are the direct and indirect contributions of the ecosystems to humankind's well-being (TEEB 2008)[1]. The economic valuation of ecosystem services is a way of valuing the many benefits that nature provides and helps to 'make the contribution of nature to livelihoods and economies visible'. The range of services that the ecosystems provide and on which all life forms depend can be broadly classified as provisioning (e.g. food, fish, fuel, fibre, water), regulation (e.g. climate regulation, flood or drought control, coastal protection, decrease in soil erosion, nutrient recycling), cultural (e.g. spiritual, aesthetic, and educational), and supporting (e.g. soil formation, primary productivity, biogeochemistry). These services can also be bundled under total economic value (TEV) of ecosystems to society, encompassing both use and non-use values.

Ecosystem services enable our survival and improve the quality of life. According to TEEB, ecosystem services can be categorized into four types:

- **Provisioning services** are the products obtained from ecosystems such as food, freshwater, wood, fibre, genetic resources, and medicines
- **Regulating services** are the benefits obtained from the regulation of ecosystem processes such as climate regulation, natural hazards regulation, water purification, and waste management, pollination, or pest control
- **Supporting services** include non-material benefits obtained from ecosystems (e.g. nutrient cycling, soil formation, primary production)
- **Cultural services** include non-material benefits that people obtain from ecosystems such as spiritual enrichment, intellectual development, recreational activities, and aesthetic values

It is being increasingly recognized that forests provide a range of goods and services, some of which have significant economic values. The economic value of a natural resource can be defined as the sum of the discounted present values of the flows of all goods and services from that resource. The Millennium Ecosystem Assessment, carried out between 2001 and 2005, placed humankind's well-being as the central focus of the assessment and recognized how biodiversity and ecosystems also have intrinsic values. Some ecosystem services are more difficult to value, and, therefore, many decisions continue to be made in the absence of a detailed analysis of the full costs, risks, and benefits involved (Millennium Ecosystem Assessment 2005)[2].

The goods and services provided by the ecosystem can be divided into two groups for valuation: (i) marketed goods and (ii) non-marketed goods. In the case of marketed goods, the market price may not always be an adequate economic value due to market failure. In such a context, shadow prices are usually taken into consideration as the surrogate market price. Among non-marketed goods, certain goods and services may have a close substitute in the market which could help in the valuation process. It can be categorized as tangible and intangible benefits. It is difficult to place a price tag on all these ecosystem services

[1] TEEB. 2008. *An Interim Report*. European Communities
[2] Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being*: *Synthesis*. Washington, DC: Island Press

provided by forests. Hence, economists have formulated different methodologies to evaluate such ecosystem services.

A valuation is a powerful tool for decision-making. There is a need for valuation because the environment offers countless services that, in essence, are free and do not have any traditional 'market values' attached. These include biodiversity conservation, clean air, or flood control. Unfortunately, humankind takes these services and their benefits for granted. Therefore, effective decisions must be taken regularly, for example, whether a road should be built through a forest stretch or should there be an alternative, instead, is a critical decision. For this, methods must be devised to help in valuing the various benefits a forest provides. Then, a cost-benefit analysis of the planned project should be done. However, for this to be of value, special care must be taken to ensure that the benefits of a forest (whether for provisioning, regulatory, or supporting services) are not undervalued.

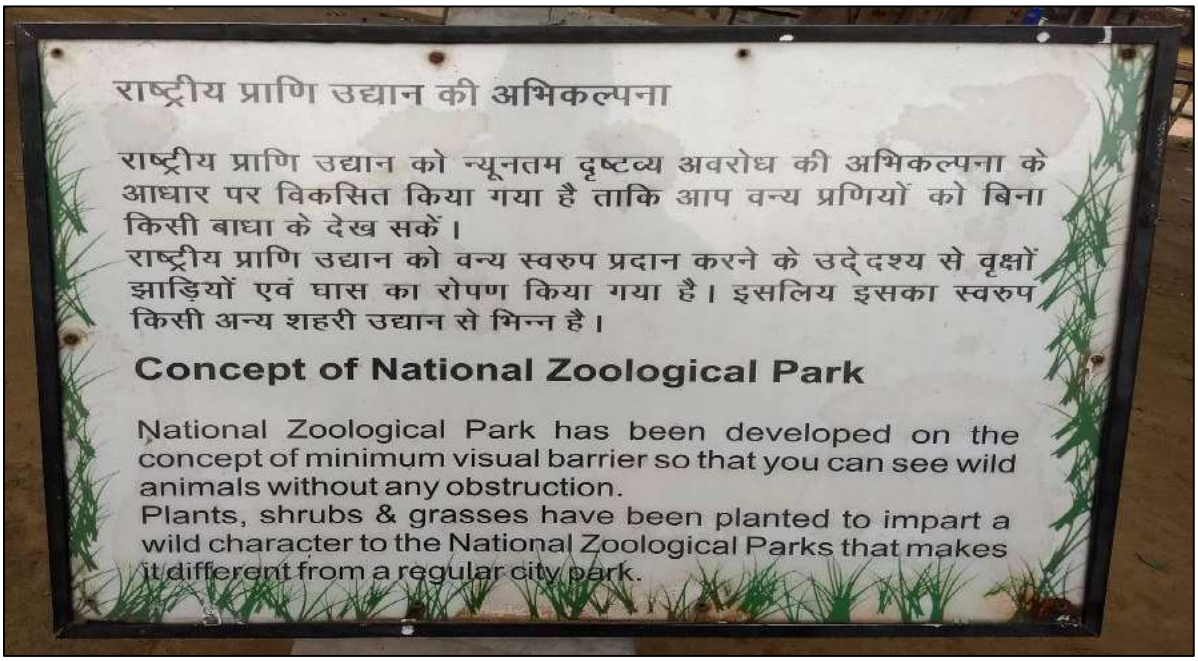
An economic valuation helps in capturing the value of ecosystem services and quantify the trade-offs resulting from decision-making (Salcone, Brander, and Seidl 2016)[3]. It also takes into account the demands and needs of future generations and addresses issues of inter-generational equity. If an industry, for example, impacts forests, the valuation of ecosystem services can guide decision-makers, who seldom look beyond the aesthetic beauty of forests. Most importantly, it underscores the fact that our actions have consequences that would be felt only years later or on downstream communities, and these temporal or spatial ramifications should be captured in quantifiable terms.

Thus, it is necessary to realize the value of ecosystem services to understand the contribution of these services to societal and overall human development.

[3] Salcone J, L Brander, and A Seidl. 2016. Guidance manual on economic valuation of marine and coastal ecosystem services in the Pacific. *Report to the MACBIO Project,* GIZ, IUCN, SPREP, Suva, Fiji

About National Zoological Park

The foundation of the Delhi zoo was laid in 1953 and officially inaugurated on 1 November 1959. The zoo was given the status of 'National Zoological Park' with the prime objective of it being the model zoo in the country. The zoo covers a total area of 176 acres and overlooks the cultural landscape of the Old Fort. The zoo is home to several species of mammals, birds, and reptiles from around the world. As of 2018, there are 40 species of endangered animals under Schedule I and II categories; 35 species of animals under Schedule III and IV categories; and 29 species of exotic animals as specified under the Indian Wildlife (Protection) Act, 1972[4]. In 2017–18, there were approximately 149 animal births of species such as Swamp deer (*Rucervus duvaucelii*), Sangai deer (*Rucervus eldii eldii*), Hippopotamus (*Hippopotamus sps*), Goral (*Naemorhedus goral*), Silver Pheasant (*Lophura nycthemera*), Finch, Zebra (Equus sps) among others.



Picture 1: Concept of National Zoological Park

The zoo is managed under different sections such as administrative, animal, veterinary, sanitary, commissary, education, research, garden, security, and maintenance. The zoo's budgetary allocation in 2017–18 was INR 4100 lakh with an expenditure of 4096.57 lakhs. In 2017–18, 2,709,311 visitors came to the zoo, out of which 2,687,325 were domestic tourists and 21,986 were foreign tourists. Over the years, the number of visitors thronging the zoo has been increasing, which is also an indication of it being a prime tourist spot in Delhi. In 2017–18, INR 1218.80 lakh was collected as revenue. Of this, INR 1022.23 lakh came from the entry fees and INR 196.57 lakh from the license fees from the contractors, who used the zoo space.

The Delhi zoo campus not only ensures infrastructural facilities for animal enclosures, hospitals, and offices but also harbours natural vegetation patches and wetlands which are important habitats for the local flora and fauna. These natural areas provide various ecosystem services particularly to the zoo visitors and the city of Delhi at large. The zoo,

[4] Details available at http://nzpnewdelhi.gov.in/WriteReadData/LINKS/annual%20report19029332-6b6b-4326-8fdf-dacbb9de4707.pdf *last accessed on January 15, 2020.*

along with its prime functions of providing ex-situ conservation and recreational and educational services, provides additional services of biodiversity conservation of free-ranging flora and fauna, carbon storage and sequestration, employment generation, improvement of air quality, mitigation of urban heat island (UHI), cultural services, noise attenuation, and so on. Therefore, to highlight the park's significance and understand its role in environmental conservation, it is necessary to carry out an economic valuation of these ecosystem services.

The Central Zoo Authority (CZA) requested The Energy and Resources Institute (TERI) to conduct a study titled 'Economic valuation of ecosystem services of National Zoological Park, New Delhi' to understand the annual value of key ecosystem services provided by the zoo. Based on the inception meeting held on December 3, 2019; six key ecosystem services were finalized for the study such as biodiversity conservation, the surrogate value of land, carbon storage, and sequestration, employment generation, recreational and cultural, education and research. The services were finalized based on the availability of limited time and resources.

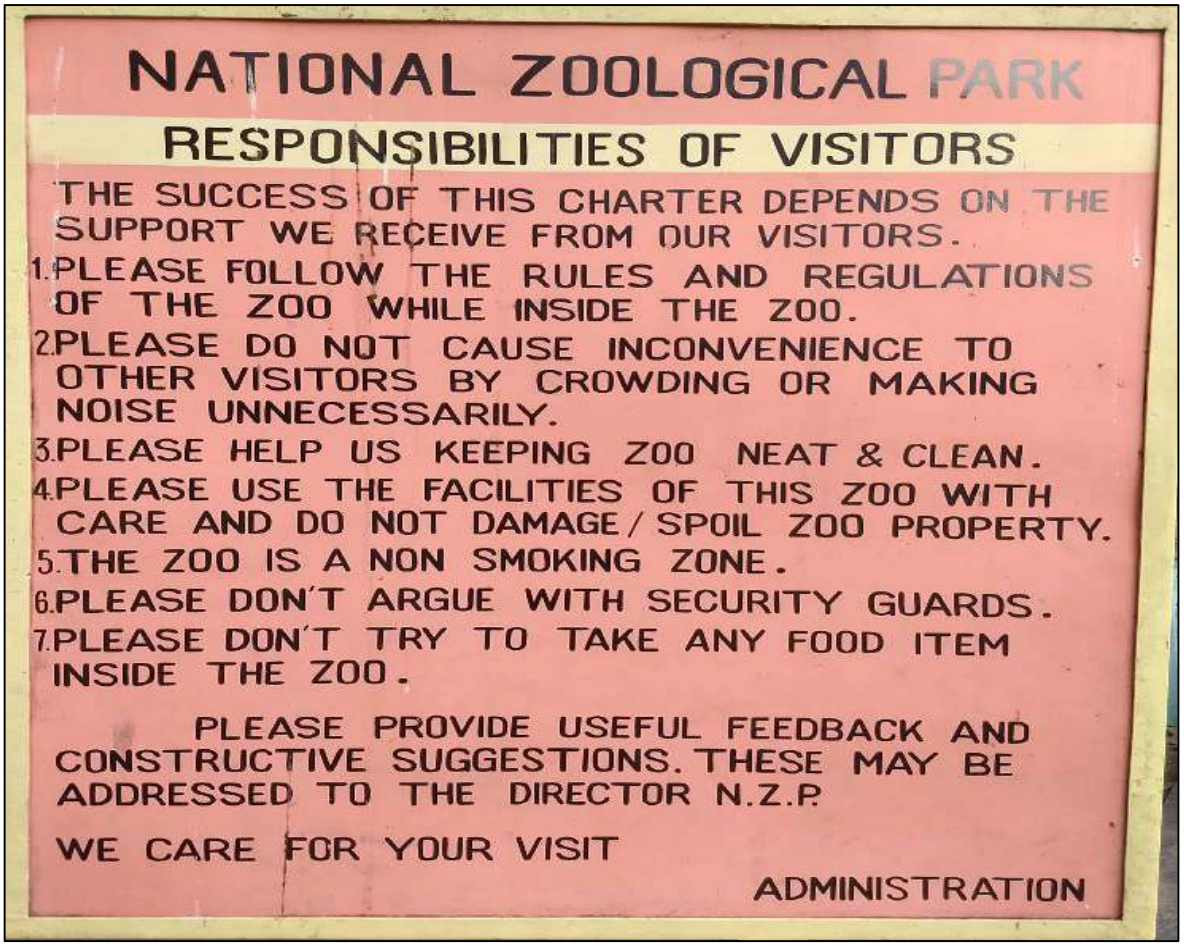
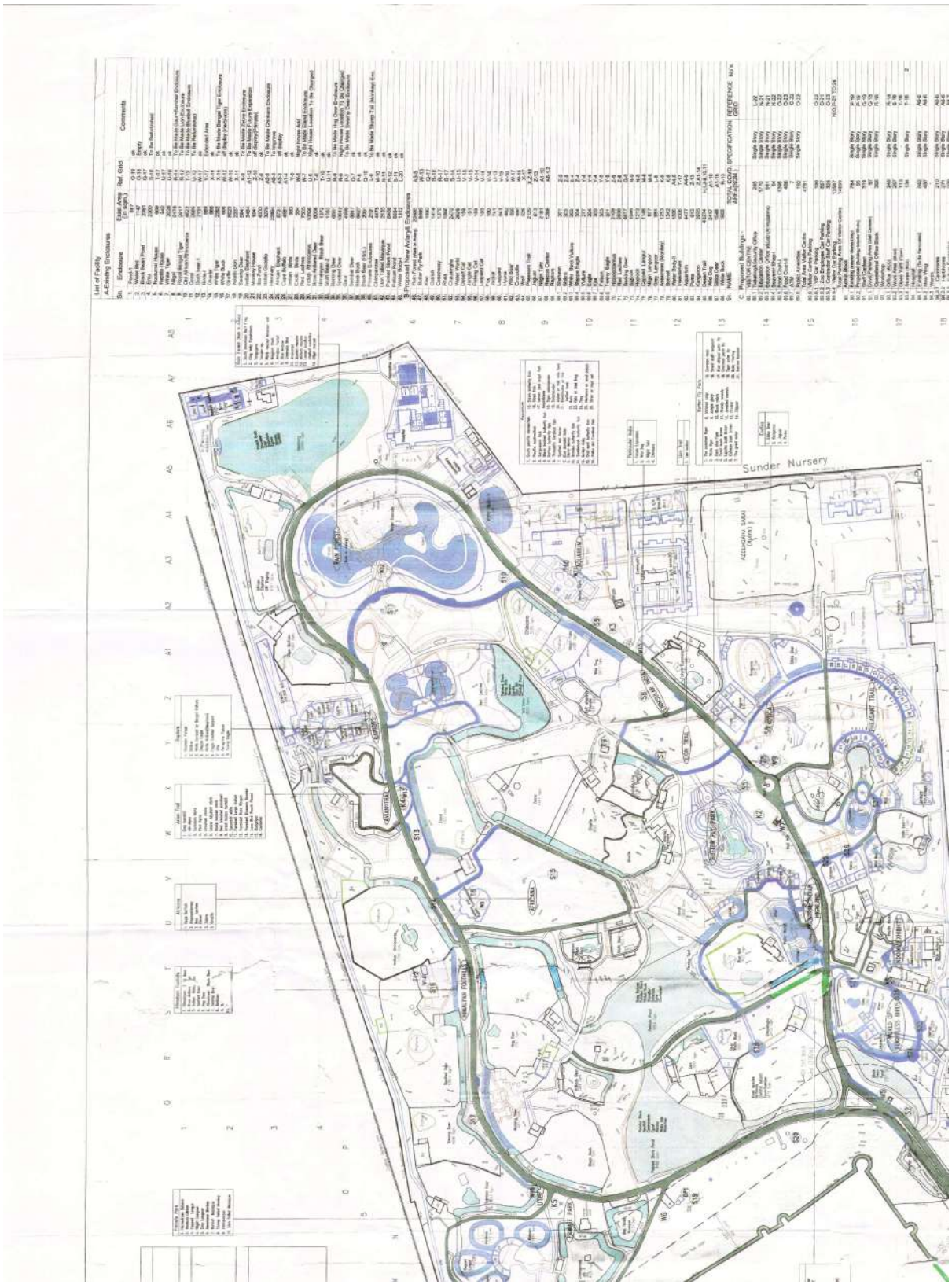


Figure 1: Responsibility of visitors in Delhi zoo

Source National Zoological Park



Map 1: National Zoological Park, New Delhi

Source National Zoological Park

Aim

Estimation of the total economic value of the ecosystem services provided by the National Zoological Park, New Delhi

Objective

To assess the total annual economic value of the ecosystem services provided by the National Zoological Park

The ecosystem services provided by the National Zoological Park are:

Use Value

Direct-use value

- Employment generation

Indirect-use value

- Carbon storage and sequestration
- Education and research
- Recreational and cultural

Non-use Value

- Biodiversity conservation
- Surrogate value of land

Valuation of Ecosystem Services of Delhi Zoo

Biodiversity Conservation

Introduction

In terms of ex-situ conservation of biodiversity, the zoo houses 73 Indian species and 26 exotic species of mammals, birds, and reptiles in its enclosure. Shortly, the zoo also plans to add species of amphibians, fish, and insects. In 2017–18, the zoo incurred an expenditure of INR 4096.57 lakhs towards the management of these animals.

The zoological park not only consists of enclosures for wild animals but also sustains a natural environment in its campus which provides habitat for several free-ranging floral and faunal species. The wetlands in the park provide habitat to various wetland bird species such as Cormorant (*Microcarbo niger*), Darter (*Anhinga melanogaster*), Spot billed duck (*Anas poecilorhyncha*), Common teal (*Anas crecca*), Painted Storks (*Mycteria leucocephala*), and Great white pelicans (*Pelecanus onocrotalus*). There are 5 species free-ranging mammals such as Palm civet (*Paradoxurus hermaphroditus*), Porcupine (*Hystrix indica*), Mongoose (*Herpestes edwardsi*), Squirrel (*Funambulus palmarum*) and bats, 76 species of birds, and 4 species of reptiles in the zoo[5]. A compilation of the floral species growing inside the zoo was conducted by Dr. H. B. Naithani in 2008. He documented 123 species of trees including *Cordia dichotoma, Ficus benghalensis, Bombax ceiba, Millettia peguensis, Leucaena leucocephala, Nyctanthes arbor-tristis,* and *Holoptelea integrifolia*.

Picture 2: Great white pelican (*Pelecanus onocrotalus*) (Left) and painted stork (*Mycteria leucocephala*) (Right) in the artificial wetlands developed by Delhi zoo

Courtesy Siddharth Edake, TERI

Methodology

The value of ex-situ conservation can be easily calculated based on the expenditure by the zoo authorities for the management of animals. However, the value of in-situ conservation is difficult to calculate because it lacks any direct attribute that can measure the value of biodiversity conservation. As biodiversity conservation is a non-use value provided by the zoo, the 'contingent valuation method' was used for identifying the visitors' willingness to

[5] Details available at http://nzpnewdelhi.gov.in/index1.aspx?lsid=1102&lev=2&lid=1107&langid=1 ***last accessed on January 15, 2020.***

pay for the service of in-situ biodiversity conservation. The prime beneficiaries of this service are citizens of Delhi-NCR. Hence, to start with, a sample was identified and a detailed questionnaire was developed to conduct the survey.

The sample size has been calculated at 90% confidence interval using the formula

$$n = N \times X/X + N-1$$

where

N = population size (for maximum sample size estimation)

$$X = Z^2 \times p \times (1 - p)/ d^2$$

where

Z = critical value of normal distribution from the statistical table

p = sample proportion

d = margin of error

The sample size for the survey was identified to be 230 people. A short survey was conducted to corroborate the questionnaire which was further refined. The questionnaire is given in Annexure 1.

The survey was done through in-person interviews and over emails. During the survey, the interviewees' viewpoints on the management of the zoo were documented and a hypothetical situation was presented to them to assess their willingness to pay for a year. The visitors were provided with a specific financial range (1–50, 50–100, 100–200, 200–500, and 500 and above) to understand their willingness to pay, and the exact amount was also documented. The data collected from the survey were compiled and analyzed to understand the results. The average value or per unit value for each range was identified and extrapolated to the total households of Delhi.

Value of Biodiversity Conservation

The survey identified that most visitors come to the zoo in groups and expressed their willingness to pay in the form of a group contribution rather than individual contribution. Hence, for this study, households were preferred over the individual population. Some visitors also expressed their unwillingness to pay as they felt that the zoo should be managed entirely by the government as the general public already contributes by paying the entry fee.

The National Capital Territory (NCT) of Delhi has 3,435,999 households, which includes both urban and rural[6]. As identified from the survey (Figure 2), 59% of the respondents were willing to pay between INR 1 and 50, 14% of the respondents were willing to pay between INR 50 and 100, and 17% of the respondents were ready to pay between INR 100 and 500. The survey also identified that almost 10% of the respondents were unwilling to contribute to the management of the zoo.

[6]Details available at http://censusindia.gov.in/2011census/PCA/PCA_Highlights/pca_highlights_file/Delhi/DATA_SHEET_PCA_DISTRICTS_NCT_OF_DELHI.pdf

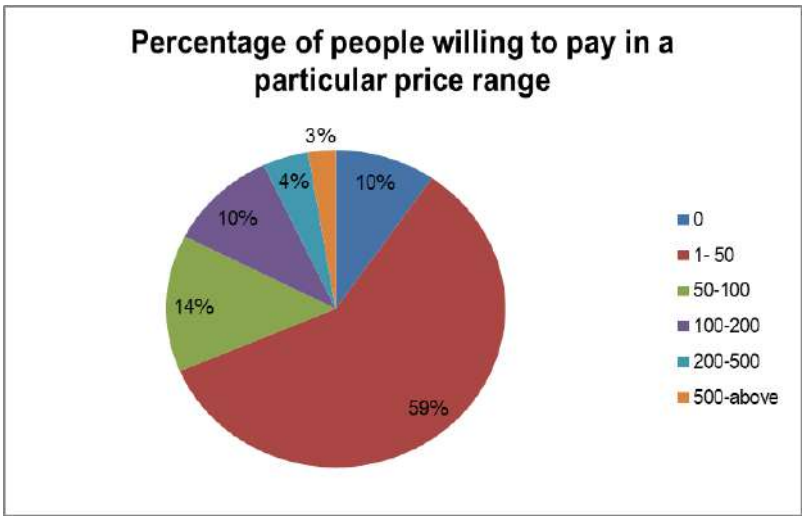


Figure 2: Percentage of people willing to pay in the particular price range for biodiversity conservation of Delhi zoo

Source TERI survey

The weighted average of the amount that the people were willing to pay in each price range was considered and extrapolated to the total households of Delhi-NCR. The annual economic value of biodiversity conservation for 2019–20 was **INR 273,281,955** or **INR 27.33 crore** (Table 1).

Table 1: Economic value of biodiversity conservation of the Delhi zoo

Range (INR)	Percentage of people willing to pay	Number of people	Average value (INR)	Value of biodiversity conservation (INR)
0	10	330,096	-	-
1–50	59	2,025,589	23	45,575,751
50–100	14	480,140	93	44,652,983
100–200	10	360,105	150	54,015,705
200–500	4	150,044	440	66,019,195
500–above	3	90,026	700	63,018,322
				273,281,955

Source TERI survey

Surrogate Value of Land

Introduction

Urban parks/gardens, wetlands, rivers, and a pristine environment provide intangible benefits that contribute towards the quality of urban life[7]. Surrogate pricing is a non-use value that people assign to economic goods even if they have never used and never will use them. The zoo is situated in a prime area of South Delhi and has a high commercial value. Instead of a zoo, the government could have used the land for real-estate development and earned high monetary benefits. But instead, the government is sacrificing on the benefits which could have been generated from the development of real estate for the conservation of biodiversity by the development of zoo.

Sunder Nagar colony which is situated in the vicinity of the National Zoological Park, was identified as the ideal location to measure the surrogate price of land for the valuation of the National Zoological Park.

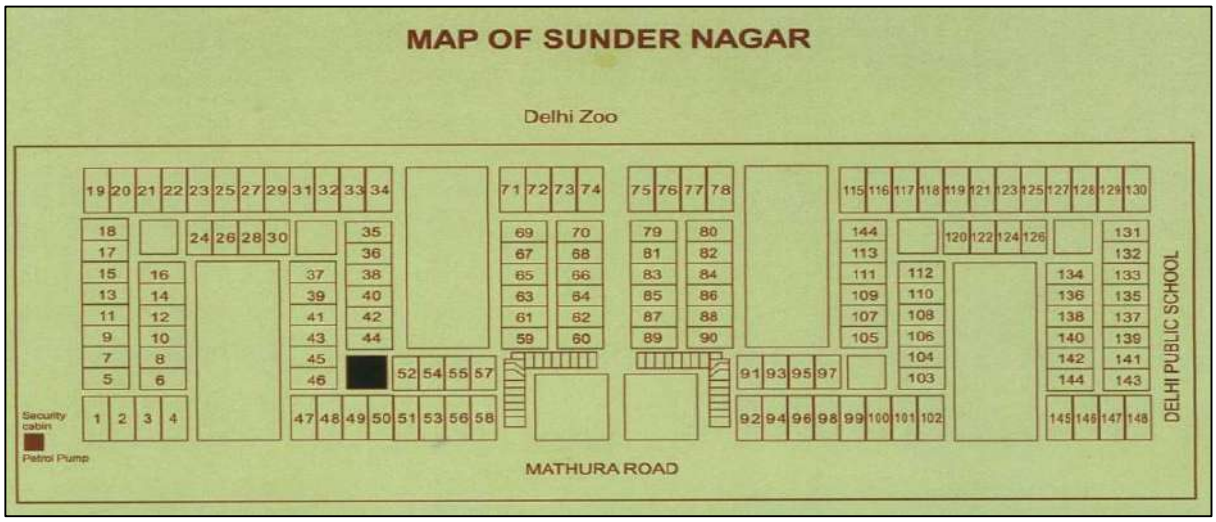


Figure 3: Map of Sunder Nagar area

Source Sunder Nagar Association

Sunder Nagar was established in the year 1950, before which the area was a barren land with the presence of few shrubs and trees. It is located adjacent to the National Zoological Park with the Purana Quila (Old Fort) on the north and the Humayun's Tomb – a world heritage monument – on the south. The colony comprises 148 bungalows on equal-sized plots (Figure 3). Since the Sunder Nagar colony is an important real estate infrastructure in close proximity to the Delhi zoo, it was necessary to study the impact of the zoo on the changing pattern of land values and property rates in Sunder Nagar.

Methodology

There are different ways of measuring the non-use value such as the contingent valuation method (CVM), hedonic price method, determination of opportunity cost, land value approach, and replacement/relocation cost. Considering the limited availability of data and

[7] Bolund, P and S Hunhammar. 1999. Ecosystem services in urban areas. *Ecological Economics* 29:293–301

time, the preferred methods for calculating the surrogate land price for the valuation of the National Zoological Park are the hedonic price method and opportunity cost.

Hedonic price method

The hedonic price method is used for estimating the economic values of the ecosystem services that directly affect market prices. It is most commonly applied to variations in housing prices that reflect the value of the local environmental attributes. This methodology links property values and the presence of features like wetlands/green spaces with variables such as distance, view, or access. In practice, many attributes jointly contribute to determining the selling price of a house. People often pay more for the charming view and the extra payment can be estimated as the value of the aesthetic and recreational services. Thus, the hedonic price method helps in quantifying the contributions of the market and non-market components of a particular good to its market price through statistical analysis.

Opportunity cost

Opportunity cost is the value of the best alternative given up. The opportunity cost approach is a very useful technique when benefits of certain uses, such as preservation, protection of habitats, cultural or historical sites, cannot be directly evaluated. This study followed the approach of opportunity cost, which here refers to the cost derived from the land adjoining the National Zoological Park. The opportunity cost of conservation is defined by the lost opportunities that occur in the process of using land for economic purposes, which in this case is Sunder Nagar[8].

Initially, an extensive literature review was undertaken by referring to the information from various governmental sources (data from NDMC, Land and Revenue Department, Delhi, etc.) and other sources (such as research papers, websites of property dealers). The literature review helped in obtaining the data regarding land cost, construction cost, circle rates[9], age factor of the property, current and past rates of the land in Sunder Nagar, and also the data regarding the major market factors responsible for the changes in land prices in the area.

A questionnaire survey was conducted with relevant stakeholders to understand their perception of the purchase of property, preference while choosing the property to be purchased, and fluctuations in the market rates. The various stakeholders included members of the Sunder Nagar Association, president of the Sunder Nagar Association, residents of the Sunder Nagar colony, property dealers in the Sunder Nagar area, and staff from the National Zoological Park. The property dealers consulted during the survey were K.S. Associates, R.K. Real Estate, Sai Real Estate Service, Intouch Associates, Sunder Properties, Access India, Link Properties Pvt. Ltd, Buniyad Real Estate Services, Global Vision, and Chaudhary Property Dealer. The questionnaire is given in Annexure 2. The surrogate value of the land being a one-time cost was not considered in the total economic valuation of the Delhi zoo.

Value of Surrogate Price of Land

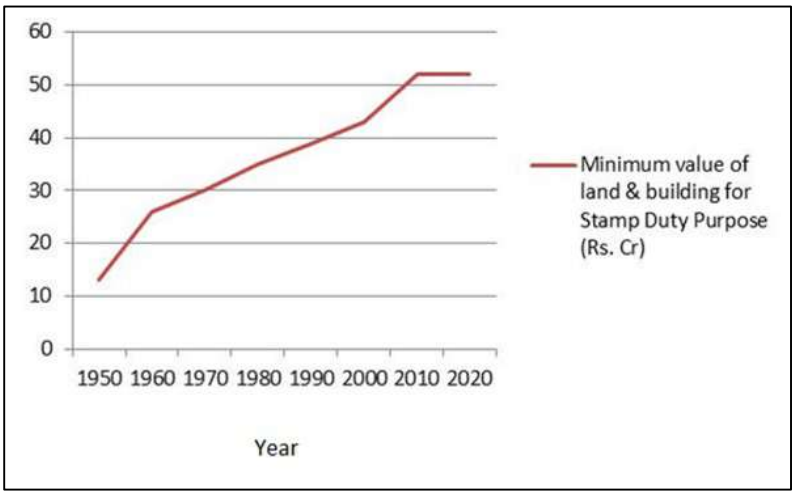
Circle rates were first introduced in Delhi in 2007 and notified under the provisions of Delhi Stamp (Prevention of Undervaluation of Instruments) Rules, 2007. The circle rates differ

[8] Machado, F H, A P Mattedi, F A Dupas, L F Silva, and F E Vergara. 2016. Estimating the opportunity costs of environmental conservation in the Feijão River watershed (São Carlos-SP, Brazil). *Brazilian Journal of Biology* 76(1): 28–35

[9] Circle rates can be defined as the minimum price at which any real estate asset has to be registered when being transferred. These rates are set by the state government and undergo revision from time to time.

based on the various categories of colonies. Sunder Nagar falls in Category A for residential plots as per the categorization by the Government of NCT, Delhi.

Figure 4: **Variation in circle rates of Sunder Nagar over the years**



Source Government of NCT, Delhi, Revenue Department, 2014

Sunder Nagar has 148 households and the circle rate of the area as of February 2020 was INR 527,307,581. Based on that, the land cost of Sunder Nagar in February 2020 was INR 78,041,521,988 or INR 7804.15 crore. Similarly, using the current circle rates of Category A areas in Delhi, the land cost of the National Zoological Park was estimated to be **INR 551,673,058,860** or **INR 55167.30 crore**.

In addition to understanding the land value of the Delhi zoo, it was also necessary to know about the impact of the Delhi zoo on the property rates of Sunder Nagar which would help to estimate the surrogate value of the land. Based on the data collected, properties facing the zoo had an average rate of INR 100 crore per plot while properties that were not zoo facing or facing Mathura Road had comparatively lower rates with an average value of INR 75 crore per plot. This indicates that the aesthetic value, greenery, and pleasant surroundings provided by the zoo can be considered as important factors for the high prices of the properties facing the zoo. Hence, the difference between the average rates of properties facing the zoo and properties away from the zoo has been used to determine the surrogate price of land. The surrogate value of land is estimated to be around **INR 250,000,000** or **INR 25 crore**.

Employment Generation

Introduction

Zoological parks, or zoos, act as sources of direct and indirect employment opportunities across many sections of society in India. Human resource is required to manage day-to-day activities in a zoo which include administration, veterinary services, maintenance, research, gardening, etc. This provides direct employment opportunities to its staff, making it one of the key services provided by the zoo. In addition to the workforce engaged in day-to-day operations, zoos also generate indirect employment opportunities in the informal sector. These constitute the local tea stalls, eateries, bookstalls, etc., situated on the periphery of the zoos. Several hawkers/sellers and other small businesses, including ice-cream sellers, balloon stalls, popcorn stalls, toy sellers, small souvenir shops, operate outside the compound of zoos in India. To ferry large numbers of visitors coming to the zoo each day, some permanent transportation modes also ply inside (e.g. battery-operated vehicles) and outside (e.g. autorickshaws, mini-buses, vans) the zoo.

In the following section, employment opportunities generated (direct and indirect) by the National Zoological Park have been assessed and the value of this service has been estimated.

Picture 3: Examples of indirect employment owing to the National Zoological Park in the form of toys

and souvenir shops (Left-top), eateries and tea stalls (Right-top), hawkers and sellers (Left and Right bottom)

Picture 4: Examples of additional direct employment owing to the National Zoological Park in the form of ATM (Left-top), dairy parlours (Centre-top), ticket counters for battery-operated vehicles (Right-top), restaurant (Left-bottom), and ticket counters with cloakrooms (Right-bottom)

Methodology

Direct employment generation

To measure the direct contribution of this service, salaries of the staff employed by the Delhi zoo in 10 sections – administrative, animal, veterinary, sanitary, commissary, education, research, garden, security, and maintenance – have been considered as part of direct employment. The staff includes permanent employees working on the zoo roster as well as contractual or outsourced employees appointed by the zoo management. Other than the permanent and contractual staff, it was also necessary to understand the benefits brought to the other stakeholders involved round the year, such as suppliers and vendors providing feed and fodder, medicines and medical equipment, and other essential services. The direct monetary employment benefits have been calculated by understanding the man-days of employment generated by the employee and the corresponding wage rates. In some cases, where the data regarding man-days were not available, direct consolidated estimates in terms of labour expenditure or wages paid from the zoo management, were considered.

Additionally, the zoo also generates employment by providing direct additional services and outsourcing contractual services to operate 4 refreshment kiosks/outlets, 12 battery-operated vehicles, 1 ATM, 1 restaurant situated next to the ticketing counter of the zoo, and a parking complex. These data were collected through key informant interviews with the respective contractors to generate information on the number of people employed and the revenue generated annually by these entities.

Indirect employment generation

A questionnaire survey was undertaken to collate data on the indirect employment benefits generated by the zoo by targeting the informal sector. This sector consists of local transporters including auto-rickshaws and cycle-rickshaws, local tea stalls, cold drink stalls, toys, and souvenir stalls, eateries selling momos, *chole kulche*, *chole bhature*, *parathe*, etc., hawkers/sellers, and other small businesses comprising ice-cream sellers, mask sellers, candy floss sellers, balloon sellers, and snack sellers selling *kachori*, *golgappe*, popcorn, peanuts and *chana*, bhel, and tender coconut. The questionnaire survey gathered data on the number of people employed and the revenue generated annually by the informal sector. The detailed questionnaire is provided in Annexure 3. In some cases, where it was not possible to reach out to the entire sample (e.g. auto-rickshaw drivers), the number of individuals employed and the income generated by an individual were extrapolated to the total number of auto-rickshaw drivers operating near the zoo.

Picture 5: Data collection from the parking lot (Left-top), hawkers (Centre-top), eateries selling momos (Right-top), local transporters (Left-bottom), restaurant (Centre-bottom), and other small businesses (Right-bottom) by using the questionnaire method prepared by TERI

Value of Employment Generation[10]

The employment benefits generated in the form of direct employment amounts to INR **5 crore** annually, which include yearly salaries of 86 permanent zoo staff members. Additionally, the costs/staff wages incurred for the contractual staff amount to **INR 3.27 crore** annually. This has been calculated as follows:

Cost for contractual staff = Daily wage rate (INR 571) × Man-days of employment generated by the contractual employee per year (312 days) × No. of contractual employees (184)

In terms of direct additional services, the zoo provides space to private contractors for operating 4 refreshment outlets/kiosks, 12 battery-operated vehicles, 1 restaurant, 1 cloakroom, 1 ATM, and a parking complex. The contractors pay 10% of their annual revenue to the zoo authority as a yearly contractual fee. The data collected through this survey indicate that the zoo receives an annual revenue of INR 2.20 crore from the private contractors. Hence, the total annual revenue generated from the contractors amounts to **INR 22.04 crore** (Table 2).

Table 2: Additional services provided by the zoo leading to employment

Additional services due to the zoo leading to employment	**Yearly income to the zoo (10% of the total revenue)**	**Number**	**Total revenue generated by the contractor**
Battery-operated vehicles	3,985,224	12	39,852,240
Parking complex	5,993,064	1	59,930,640
Cloak room	87,504	1	875,040
Restaurant outside the zoo + refreshment outlets/kiosks	11,945,496	1+4	119,454,960
Total	**22,043,280**		**220,432,800**

As per the data collected through the questionnaire surveys, indirect employment generates **INR 1.87 crore** annually for 112 individuals (constituting local transporters, shops/stalls, and hawkers/sellers/small businesses) (Table 3).

Table 3: Indirect employment provided by the Delhi zoo

Indirect employment	**Annual income (INR)**	**Number of people employed**	**Total income (INR)**
Shop/stalls			
Eateries (momos, chole kulche, chole bhature, parathe, *etc.)*	132,000	15	1980,000
Tea	216,000	5	1,080,000

[10] The data on employment generated in the form of direct employment and revenue generated from the restaurant were unavailable and, hence, not considered in these calculations.

Indirect employment	Annual income (INR)	Number of people employed	Total income (INR)
Cold drinks	240,000	1	240,000
Ice cream	120,000	5	600,000
Toy and souvenirs	276,000	1	276,000
Local transporters			
Autorickshaws	300,000	30	9,000,000
Cycle-rickshaws	180,000	15	2,700,000
Hawkers/sellers/other small businesses			
Ice cream	72,000	5	360,000
Mask	72,000	3	216,000
Candy floss	72,000	5	360,000
Balloon	72,000	5	360,000
Snacks (kachori, golgappe, *popcorn, peanuts and* chana, bhel, *tender coconuts)*	72,000	20	1,440,000
Mehendiwali	72,000	2	144,000
Total		**112**	**18,756,000**

Source TERI survey

Based on the annual values generated from direct employment and indirect employment from the Delhi zoo, the annual economic value of employment generation for 2019–20 is **INR 321,968,768, INR 32.19 crore**.

Gap Analysis

Though the annual economic value of employment generation by assessing direct employment and indirect employment has been estimated to be INR 32.19 crore for 2019–20, this does not include the cost incurred for stakeholders such as suppliers and vendors providing feed and fodder, medicines, and medical equipment, and other essential services needed throughout the year. In case these data are made available in the future, it will provide a more robust picture and the exact value of the services in the form of employment generation.

Education and Research

Introduction

The main aim of Delhi zoo is to provide education, conduct research, create awareness and generate interest among the visitors and inspire them to support and contribute to the cause of conservation of wildlife and its habitat. To achieve this, the zoo authorities are implementing various initiatives such as preparing brochures, providing a platform for participative activities, providing information related to every animal in the zoo on signage boards, and maintaining information booths. The zoo is also proactively involved in organizing conservation, educational, and awareness programmes to spread awareness among the people.

As research is one of the key objectives of the zoo, it has been encouraging and helping young researchers to carry out activities such as maintaining study books, animal history cards, and carrying out chemical analysis, pathology, and parasitology of endangered animal species. Several research studies have already been undertaken in the zoo[11]. The details are listed as follows:

- Breeding patterns in pheasants by a student from the School of Environment Management, GGS Indraprastha University, Dwarka
- Internship of 13 BSc Zoology second-year students from S. G. T. B. Khalsa College, Delhi University
- Study on Asiatic Lion in captivity by a BSc Zoology student from S. G. T. B. Khalsa College, Delhi University
- Behavioral study of Sangai deer by a research scholar from the School of Environment Management, GGS Indraprastha University, Dwarka
- Internship of an MSc Wildlife Science student from Amity University, Sector 125, Noida
- Case study by a student pursuing MPhil/Ph.D. from the School of Life Sciences, JNU
- Internship by a student studying Bachelor of Applied Science at Unitec Institute of Technology, Auckland

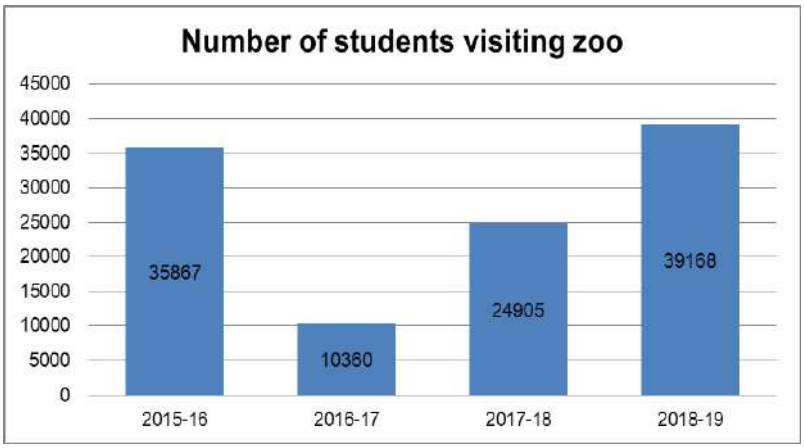


Figure 5: Number of students visiting zoos over the years

Source National Zoological Park

Schoolchildren regularly visit the zoo as part of their curriculum to hone their learning skills on wildlife, its issues, and conservation. The number of schoolchildren visiting the zoo over the years is provided in Figure 5.

[11] Details available at http://nzpnewdelhi.gov.in/

The zoo conducts regular awareness activities on important environmental days such as world wetlands day, world wildlife day, world forest day, etc. The important environmental days and potential activities proposed by the zoo authorities are provided on the zoo website[12]. In 2017–18, the zoo conducted *Nukkad natak* (street plays), interaction with

NATIONAL ZOOLOGICAL PARK (DELHI ZOO)
MATHURA ROAD, NEW DELHI -03
WILDLIFE WEEK -2019
Programme Sheet

S.No.	Day & Time	Activity	Eligibility/Group	Preparation
1	2nd Oct., 2019 (Wednesday)	**Inauguration of Wildlife Week.**	Invited Schools and Others	Zoo Walk
2	3rd Oct., 2019 (Thursday)	**On the spot painting competition**	**Group-A** (1st to 5th class) **Group-B** (6th to 8th class) **Group-C** (9th & 10th class) **Group-D** (11th & 12th class) **Group-E** (Physically Challenged School Students)	Please bring Clipboard, Colors, Pencil, Eraser etc. Only Drawing Sheet will be provided by National Zoological Park for drawing and painting purpose.
3	4th Oct., 2019 (Friday)	**Clay modeling**	Visually Challenged student of 6th to 12th class	Clay will be provided for modeling by National Zoological Park Topic – "Preserve wildlife"
4	5th Oct., 2019 (Saturday)	**Poster making competition**	University Students	Topic-"Conservation of Tigers" on sheet having size 2.5 x 1.5 square feet
		Rangoli competition	Class 9th to 12th	Rangoli competition on "Preserve Wildlife"
5	6th Oct., 2019 (Sunday)	**Expert Talk**	By Expert	Topic related to "Conservation Wildlife"
6	7th Oct., 2019 (Monday)	**Debate**	Class 10th to 12th	Topic-"Role of Zoo in conservation of Wildlife"
		Mehandi Competition	9th to 12th Class	Mehandi Competition on "Preserve Wildlife"
7	8th Oct., 2019 (Tuesday)	**Open Wildlife Quiz**	6th to 12th Class	Simple questions related to wildlife. Medium – English/Hindi
8	2nd to 8th Oct. 2019 (Wednesday to Tuesday)	**Amateur Photography**	Only Amateur photographers can take part	Recent photograph in size 10" × 8" either in color or black and white photos shall be submitted to N.Z.P. in between 10:00 AM to 4:30 PM. during 2nd to 8th Oct. 2019. These photographs shall be shot inside the N.Z.P. Prize winning photograph has to be submitted along with softcopy.

students on wildlife days, held key lectures, celebrated *Van Mahotsav*, Tiger Day, and so on. The recent events conducted by the zoo authorities during 'Wildlife Week' are given in Figure 6.

Figure 6: Activities organized by the zoo during 'Wildlife Week', 2019

Source National Zoological Park

[12] Details available at http://nzpnewdelhi.gov.in/index1.aspx?lsid=1106&lev=2&lid=1104&langid=1

Methodology

Initially, an extensive review of the literature was undertaken to understand the number and type of research-specific activities and educational programmes carried out in the zoo by reviewing secondary literature available as well as information from the official Delhi zoo website. The information regarding the number of tourists visiting the zoo and different research studies conducted and proposed in the zoo were also collected with the help of the authorities apart from the data available on the Delhi zoo website.

Developing a questionnaire and conducting a pilot survey

A detailed questionnaire was developed for collecting the primary information and visitors' responses about the zoo. Pilot surveys were conducted in the zoo based on which the questionnaire was finalized.

Determining the sample size

The sample size has been calculated at 90% confidence interval using the formula

$$n = N \times X/X + N-1$$

where

N = population size (for maximum sample size estimation); the average of the total number of visitors in the last four years has been taken, which is 2,540,289 visitors

$$X = Z^2 \times p \times (1 - p)/ d^2$$

where

X = Sample size

Z = critical value of normal distribution from the statistical table

p = sample proportion

d = margin of error

The sample size comes out to be 271.

In total, 271 visitors were surveyed through questionnaire-based interviews.

It was identified during the pilot surveys that to gain knowledge about wildlife people invest in subscribing various channels related to wildlife such as Discovery, National Geographic Channel, Animal Planet, etc.; visit various protected areas and nature reserve, and attend specific seminars or workshops related to wildlife. However, they can have the same learning experience by visiting the zoo. Since the zoo is the prime medium responsible for awareness about wildlife, we took an approach to document the sources preferred by the visitors which provides information about animals. Hence during the survey, the medium through which people acquire knowledge about animals and the associated cost (e.g. visit protected areas, watching wildlife-related television channels, taking tuitions, going to camps) was documented. The annual investment done by the visitors to gain knowledge about wildlife, other than the zoo, is the value of the educational and research service provided by the zoo. The detailed questionnaire is given in Annexure 4. The average value or per unit value was identified and extrapolated to the number of visitors in the Delhi zoo.

The information related to the on-going research studies and expenditure incurred on awareness programmes was not available and, hence, not included in this study.

Picture 6: Survey with visitors at Delhi zoo on education and awareness

Value of Education and Research

A total of 271 visitors, between the age groups 7 years and 57 years, were interviewed. On an average, the visitors rated the whole experience of visiting a zoo as 7.8 on a scale of 1 to 10, where 1 means 'very bad experience' and 10 indicates 'very good experience'.

The study documented that around 4% of the tourists pay tuition fees to get education and knowledge about wildlife by incurring an average annual expenditure of INR 2333. Around 73% of the visitors subscribed to various wildlife-related channels such as Discovery, National Geographic, Animal Planet, Sony, BBC Earth, for wildlife-related information and incurring an expenditure of INR 75.11, annually. But almost 24% of the tourists are not spending any amount on education and research related to wildlife.

On average, 2,540,289 people visit the zoo every year. Considering that 73% of the population visiting the zoo (1,854,411) spent on the subscription of various wildlife-related channels and another 4% (101,611) spent on tuition fees, the annual cost invested by the visitors was INR 139,284,794.2 for TV channels and INR 237,059,746 on tuition fees, respectively.

Hence, the annual economic value of employment generation for 2019–20 is **INR 37,63,44,540.4** or **INR 37.6 crore**.

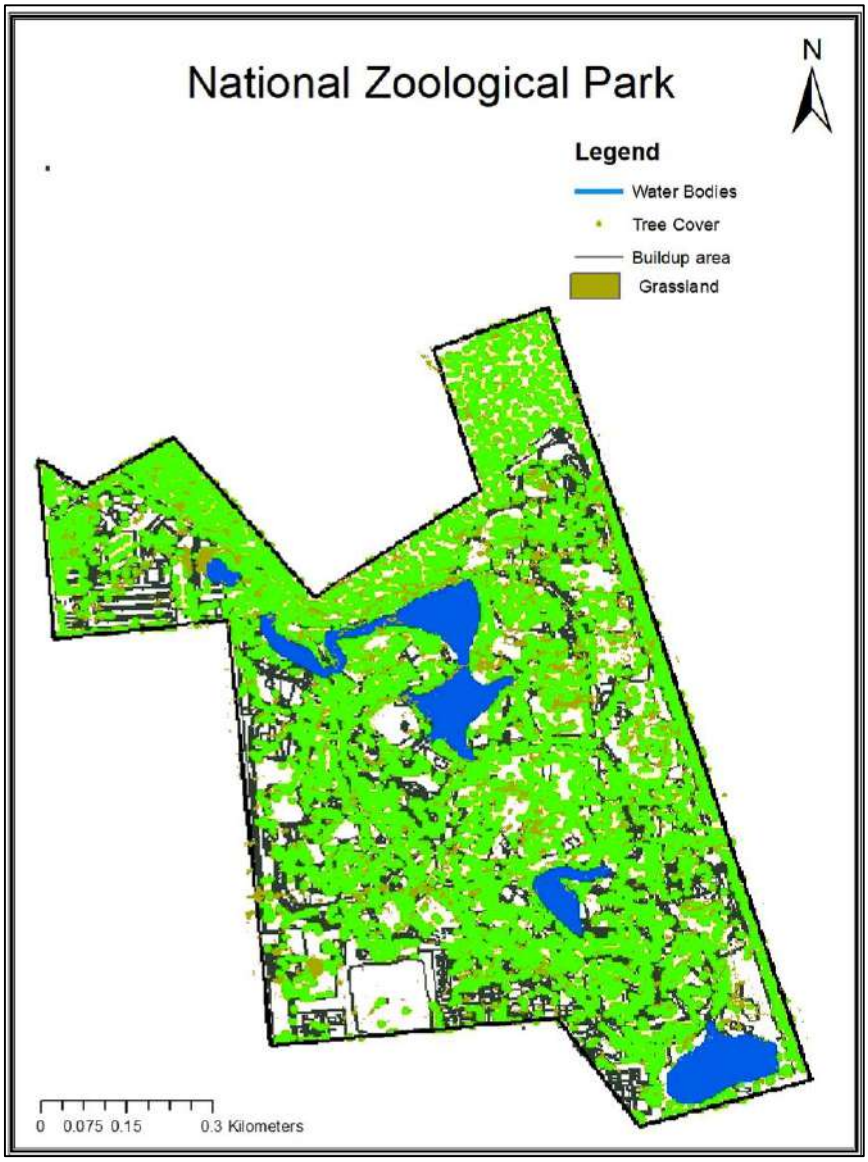
Carbon Sequestration and Storage

Introduction

The Delhi zoo, as previously described, consists of not only infrastructures such as offices and enclosures but also natural spaces in its surroundings. In terms of habitat, forests form almost 72% area (51.45 ha), grasslands form 9% area (6.02 ha), wetlands form 6% area (4.14 ha), and the built-up area covers 13% (9.46 ha) of the total area of the zoological park. The natural areas of forests, grasslands, and wetlands perform the key function of carbon sequestration, thereby reducing the pollution levels in Delhi.

Map 2: Land-use map of National Zoological Park

Note **Map not to scale**



Source **TERI**

Methodology for Assessment of Carbon Stock for Forests, Grasslands, and Wetlands

Carbon storage

The assessment of the carbon stock for forests, grasslands, and wetlands was based on the collection of primary data. The detailed methodology used for the estimation of carbon stock for all three ecosystems are presented below.

Forests

Eligible carbon pools

In a forest ecosystem, the key carbon pools are above-ground tree biomass (AGTB), below-ground tree biomass (BGTB), deadwood (DW), litter (L), and soil organic carbon (SOC). AGTB mainly includes biomass of tree bole and branches, BGTB includes biomass from the roots of the tree, DW includes biomass from fallen twigs and branches, litter includes biomass from the semi-decomposed leaf material, and SOC includes the carbon present in the soil of each pilot project site. For this study, three pools of carbon were selected – AGTB, BGTB, and SOC, as the remaining two pools, deadwood, and litter, have a very insignificant percentage in the overall value of carbon stock in the case of a zoo (Table 4). The field measurement data were collected based on an appropriate sampling strategy and statistical sampling design. A combination of systematic and stratified random sampling was adopted for data collection.

Table 4: Three pools of carbon

S. No.		Pool	Description
1	Living biomass	Above-ground biomass (AGB)	All living biomass above the soil including stem, stump, branches, bark, seeds, and foliage
		Below-ground biomass (BGB)	All living biomass of live roots. Roots which are less than 2 mm in diameter are generally excluded as they often cannot be distinguished from litter or soil organic matter
2	Soil	Soil organic matter (SOM)	Includes organic carbon in mineral and organic soils to a depth of 30 cm (FSI) and applied uniformly throughout the area

Source ISFR (2019)

Process of forest carbon assessment

The following steps were involved in the process of assessing the carbon stock in forests based on an analysis by TERI (2019)[13].

- **Delineation of project boundary:** The delineation of the selected study area was done by the following two steps: (i) use of permanent boundary markers such as rivers,

[13]TERI. 2019. *Training Manual for Capacity Building of Assam Forest Department on Carbon Stock Assessment of Forests.* New Delhi: The Energy and Resources Institute

creeks, or mountain ridges to get a permanent boundary of the field and (ii) use of tools such as satellite images, aerial photographs, global positioning system (GPS) tracking, topographic maps, or land records.

- **Stratification, mapping, and sampling design:** For stratification of the project area, collection of basic information such as land use, land cover, data on vegetation, and data on topography was done and a base map was prepared. The various strata and sub-strata were identified later. The project area was stratified into approximately homogeneous units based on various parameters such as forest type, dominant tree species, the stocking density of trees, age of trees, aspect and position of hill slopes, altitude, physical boundary, and site quality. Since the carbon stored in the vegetation largely depends upon the canopy density and forest type, these two were considered as stratification variables.
- **Shape and size of sample plots:** The required number of the permanent sample plots with appropriate sizes and shapes should be identified at the start of a project. The forest carbon measurement can be carried out in both square and circular plots. Nevertheless, circular samples are recommended for areas that were hilly and inaccessible. A square plot of 31.62 m × 31.62 m size each would be laid in each site as shown in Figure 7.

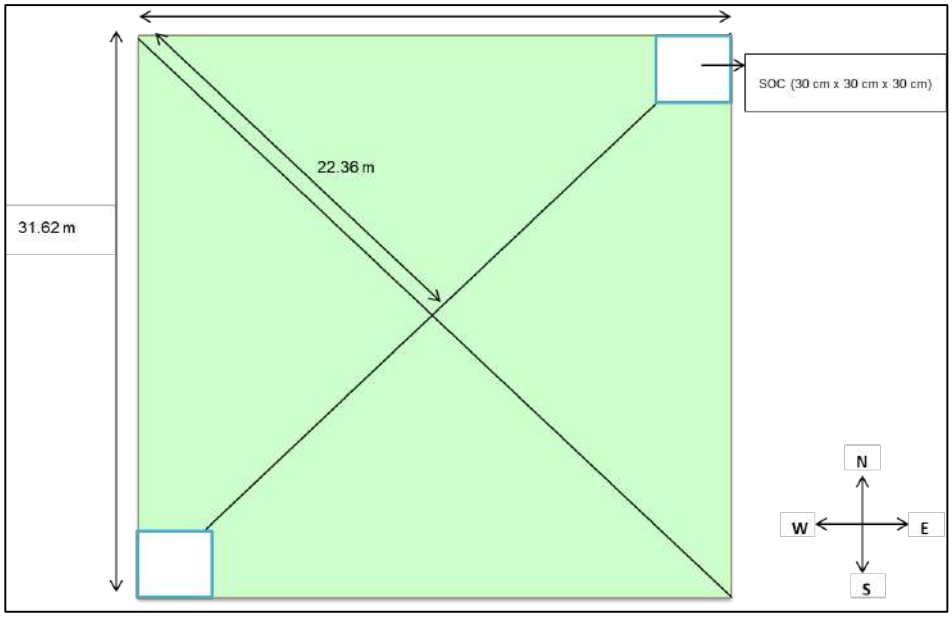


Figure 7: Permanent square plot

Estimating the number of sample plots

To measure each tree within each selected site is not only time-consuming but also impractical and infeasible. Pearson, Walker, and Brown (2005)[14] have developed a statistical tool through which one can estimate the required number of sample plots to be laid in the project site that is statistically significant. Thus, through this statistical tool, measuring only a fraction of trees from the total project area can provide true values of the biomass of the entire project area. The number of estimated sample plots to be laid out in the selected site depends upon various factors such as size and number of stratums, basic carbon density, and the standard deviation in the selected project area. In all the selected pilot sites, the

[14] Pearson, T, S Walker, and S Brown. 2005. *Sourcebook for Land Use, Land-Use Change and Forestry Projects. Winrock International and the Bio Carbon Fund of the World Bank.* Winrock International.

estimated number of sampled plots to be laid out in each pilot site is calculated using the statistical equation mentioned in Step V. The methodology for estimating the number of sample plots to be laid out in each pilot project site that is statistically significant is as follows:

Step I. Identify the desired precision level

(±10% of the mean at 95% confidence interval is frequently used)

Step II. Identify the area or preliminary data

(10–15 plots per stratum will suffice for variance analysis)

Step III. Estimate carbon stock per tree, per plot, per hectare, and mean carbon stock/ha

Step IV. Calculate the standard deviation of carbon (tC/ha) of all plots

Step V. Calculate the number of plots using the following statistical equation:

$$n = \frac{N * t_{VAL}^{2} * \left(\sum_{i} w_i \right)}{}$$

where

n = Number of sample plots required for estimation of biomass stocks within the project boundary; dimensionless

N = Total number of possible sample plots within the project boundary (i.e. the sampling space or the population); dimensionless

E = Desired level of precision

t_{VAL} = Two-sided *t*-value, at infinite degrees of freedom, for the required confidence level; dimensionless

w_i = Relative weight of the area of stratum *i* (i.e. the area of the stratum *i* divided by the project area); dimensionless

s = Estimated standard deviation of biomass or volume (t d.m. ha-1) in stratum *i* (when it is not available, then instead 50% of the estimated volume, biomass, etc. is used) (as per IPCC's *Good Practice Guidelines*, 2003).

i = 1, 2, 3 biomass stock estimation for strata *i* within the project boundary

Instead of calculating the statistically significant number of sample plots in the project site, a preliminary data collection and physical measurement of vegetation were carried out.

Laying out of permanent sample plots

The main plot of size 31.62 m x 31.62 m (area 0.1 ha) was laid as mentioned by the Forest Survey of India (illustrated in Figure 7) and the biomass within the plot was calculated. Starting from one corner of the plot, the trees were tagged so that the same tree is not

measured twice and every tree was covered within the plot. Within this 0.1-ha plot, two pits of 30 cm × 30 cm × 30 cm were dug at two corners (northeast and southwest) to calculate the biomass of soil carbon as described in the following steps:

Picture 7: Laying of sample plots

Measurement of above-ground biomass

A non-destructive method was used to estimate the above-ground biomass. In this method, the diameter at breast height (DBH) and the height of the trees falling within the sample plot were measured. The measurements were tabulated along with the sample plot number, the botanical name of the tree, local name of the tree, and remarks (refer to Annexure 5). To calculate the biomass of every single tree species, volume equation, wood density (g/cm^3), and biomass expansion factor was applied. Volume equations are regression function in volume, diameter, and height for each species**.**

For the estimation of DBH, the girth of the tree was measured at 1.37 m above the ground using a measuring tape. The different diameter measuring points in different situations are shown in Figure 8. For an incidence, if the girth of a sample tree has forked stem from the ground, then both the stems are measured individually.

Picture 8: Measurement of the girth (Left) and height (Right) of the tree

There are different methods for measuring the height of the tree. One method employed in this study was by using an altimeter. In this, the top of the tree was viewed through the altimeter from a distance far enough to see the full height of the tree. The altimeter reading, the distance between the tree and the person, and the height of the person were noted down to calculate the tree height. The reading in the altimeter was shown in percentage. The height of the tree was calculated as depicted in Figure 8.

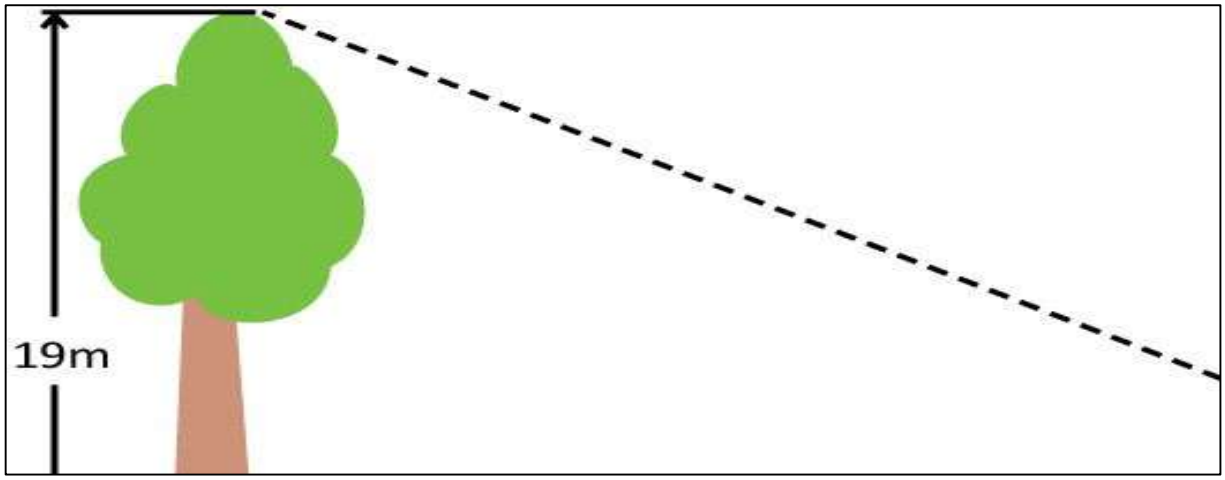


Figure 8: Using altimeter to calculate tree height on a leveled ground

Measurement of below-ground biomass

It was measured using a ratio (usually, root to shoot ratio = 0.27) to above-ground biomass which has already been established by various researchers. The *Good Practice Guidelines* (IPCC 2006) also provide ratios for six major global forest types. The FSI has selectively used these defaults to arrive at the carbon number.

Measurement of soil organic carbon

Soil organic carbon was determined through samples collected from the default depth as prescribed by ISFR (2019). For collecting data on soil carbon, two plots of size 1 m × 1 m each were laid out within the main plot. At the center of these two sub-plots, a pit of 30 cm × 30 cm × 30 cm was dug and the composite sample of 200 g of soil was kept for organic carbon analysis. All samples were then placed into zipped pouches which were labeled appropriately. Samples of soil were analyzed from the standard soil labs using the Walkley-Black method and further, the value of soil organic carbon was used for calculation.

Data analysis

Above-ground biomass

Picture 9: Collection of soil samples at the Delhi zoo

The selection of the appropriate allometric equation is a crucial step in estimating above-ground tree biomass (AGTB). Allometric equations for biomass usually include information on trunk diameter at breast height, DBH (in cm), total tree height, *H* (in m), and wood-specific gravity (in g/cm^3).

Above-ground biomass (AGB) = Volume (V) × Wood density (WD) × Biomass expansion factor (BEF)

BEF value **-** Moderately dense forest – 2.5

After taking the sum of all the individual weights (in kg) of a sampling plot and dividing it by the area of a sampling plot (1000 m^2), the biomass stock density was attained. The biomass stock density of a sampling plot was converted to carbon stock densities after multiplying with the IPCC (2006)[15] default carbon fraction of 0.47.

Below ground biomass

The below-ground biomass was estimated as 27% of the above-ground biomass.

BGB = AGB × 0.27 (IPCC default value)

where

BGB = Below-ground biomass and AGB = Above ground biomass

[15] IPCC. 2006. *Good Practices Guidelines for National Greenhouse Gas Inventories*. Switzerland: Intergovernmental Panel on Climate Change

Soil organic carbon

Soil samples were collected at 0–30 cm depth. Samples of exactly 200 g were taken and transferred to pre-weighed sampling bags. Wet weights of soils were determined in the field with 0.1 g precision. Samples were then transported to the laboratory and oven-dried (70°C) until a constant weight was attained to determine the water content. Samples collected were composted and well-mixed (per sampling plot) and then prepared for carbon measurement by removing stones and plant residue > 2 mm as well as by grinding. The carbon stock density of soil organic carbon was calculated as (Pearson, Brown, and Birdsey 2007)[16]:

$SOC = rb \times d \times \%C$

where

SOC = Soil organic carbon stock per unit area (t/ha)

rb = Soil bulk density (g/cm^3) – default value is 1.2

d = Total depth at which sample is taken (cm)

%C = Carbon concentration

Total carbon stock density

The carbon stock density was calculated by summing the carbon stock densities of the individual carbon pools of that stratum using the following formula:

$\Delta C = \Delta C_{AGB} + \Delta C_{BGB} + \Delta SOC$

where

C = Carbon stock density

C_{AGB} = Carbon in above-ground biomass

C_{BGB} = Carbon in below-ground biomass

SOC = Soil organic carbon

The total carbon stock is then converted to tonnes of CO_2 equivalent by multiplying it by 44/12, or 3.67 (Pearson, Brown, and Birdsey 2007).

Grasslands

According to IPCC (2006), the methodology for carbon stock assessment of grasslands will involve an estimation of changes in carbon stock from five-carbon pools (i.e. above-ground biomass, below-ground biomass, deadwood, litter, and soil organic matter). The estimation of changes in carbon stocks in biomass requires an estimate of changes in stocks of above-

[16] Pearson, T R, S L Brown, and R A Birdsey. 2007. *Measurement Guidelines for the Sequestration of Forest Carbon*. US: Northern Research Station, Department of Agriculture

ground biomass and changes in carbon stocks of below-ground biomass. Dead organic matter (deadwood and litter) are not the priority pools for the grassland land-use category since there is a negligible accumulation of carbon in them.

The annual change in carbon stocks is a sum of annual changes in different carbon pools. Distribution of carbon in different carbon pools varies in different land-use categories. For savanna, grasslands, pastures, and cropland, the soil is dominant over vegetation in storing carbon. Therefore, the estimation of soil carbon is critical for the given land-use category (UNDP 2014)[17].

Methodology

The gain-loss method is mostly used for estimating the carbon stock change in biomass. This method involves estimating the area of grasslands according to management categories, average annual growth, and loss of biomass stocks. This requires an estimation of the area under grasslands according to a different climate or ecological zones or grassland types, disturbance regime, management regime, or other factors that significantly affect biomass carbon pools and the growth and loss of biomass according to different grassland types (IPCC 2006).

The methodology for carbon stock assessment of grasslands was followed, as specified by IPCC (2006), TERI (2019), and UNDP (2014). The steps followed for carbon stock assessment of grasslands are:

- **Delineation of the study area:** The delineation of the selected study area was done by using tools such as satellite images, aerial photographs, global positioning system (GPS) tracking, topographic maps, or land records.

- **Sample designing:** The purpose of sample designing is to estimate the number of sample plots because measuring every sample plot within the selected area is not possible and time-consuming. For this, preliminary data collection and measurements of vegetation patches are done before the actual fieldwork. After that, the desired precision level is identified. The variance analysis is done by using data of 10–15 plots. The estimate of the number of plots is done statistically by using the formula (Pearson, Walker, and Brown 2005) as discussed in the estimation of carbon stocks in forests.

- **Identification of carbon pools:** Eligible carbon pools for grasslands — above-ground biomass, below-ground biomass, and soil organic carbon — were assessed using the methodology as described in IPCC (2006).

- **Laying of sample plots:** A sample plot of 5 m x 5 m square was laid down. Within this main plot, two quadrates of 1 m × 1 m at the two corners, i.e. northeast and southwest, were laid for the estimation of grass biomass (Figure 9).

[17] UNDP (United Nations Development Programme). 2014. *Grassland Carbon Stock Calculation and Preparation of Water Balance Model for Vashlovani Protected Areas*. UNDP.

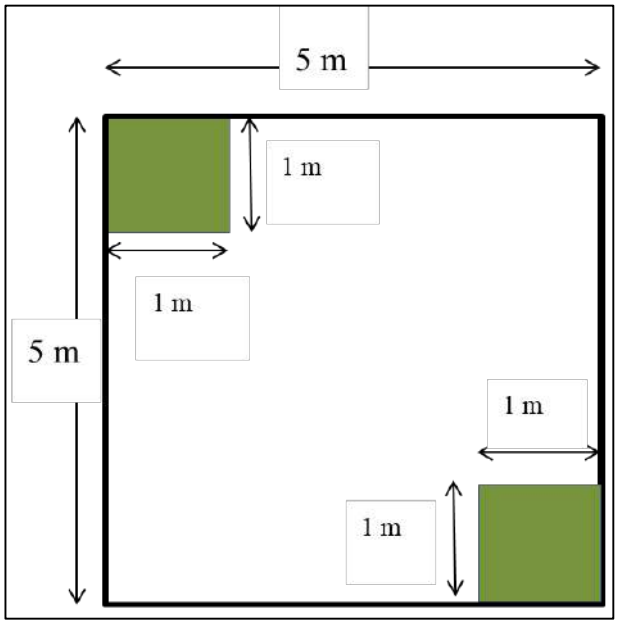


Figure 9: Diagrammatic representation of sampling plot laid for carbon stock assessment of grasslands

Source IPCC (2006)

Above-ground biomass

Above-ground biomass can be defined as all the biomass of living vegetation, both woody and herbaceous, above the soil including stems, stumps, branches, bark, seeds, and foliage (IPCC 2006). The size of the square plot for measuring the above-ground biomass was 5 m × 5 m, which is considered most suitable for grassland carbon inventory. A wooden sampling frame was placed to mark 1m² squares within the main plot for above-ground biomass harvesting. Samples of approximately 100 g were collected from each plot and recorded on a working sheet. The collected samples were then sent to the laboratory for further analysis to calculate the total dry weight.

Picture 10: Collection of grass sample at Delhi zoo

To estimate the total carbon stock, the biomass is multiplied by the carbon content of dry biomass. The default value is 0.47 tonne of C per tonne of biomass.

Therefore,

Total dry weight (kg/m²) = Total fresh weight (kg) × Subsample dry weight (g) × Sample area (m²)/Subsample fresh weight (g)

C_{AGB} = Total dry weight × 0.47

Below-ground biomass

The expansion factor was used to estimate the below-ground biomass from the above-ground biomass. For the estimation of belowground biomass, a simplified approach based on the below-ground to above-ground biomass ratio was used (IPCC 2006).

The default expansion factors of the ratio of below-ground biomass to above-ground biomass for grasslands were taken as 0.5 (IPCC 2006).

Below-ground biomass = 0.5 × Above-ground biomass

To estimate the total carbon stock, the below-ground biomass was multiplied by the carbon content of dry biomass. The default value was 0.47 tonne of C per tonne of biomass (IPCC 2006).

C_{BGB} = Total below-ground biomass × 0.47

Soil organic carbon

Soil organic carbon is determined through samples collected from the default depth as prescribed by FSI in 2017. For collecting the data on soil carbon, two subplots of 1 m × 1 m size each were laid out within the main plot. At the center of these two subplots, a pit of size 30 cm × 30 cm × 30 cm was dug and a composite sample of soil weighing around 200 g was kept for organic carbon analysis. All samples are placed in zipped pouches which were then appropriately labeled. The samples of soil were further analyzed at the standard soil laboratories and used for calculation (IPCC 2006).

Soil organic carbon is calculated based on the carbon content of soil organic matter. The content of organic carbon in the soil, estimated in percentage, needs to be converted to tonnes per hectare using bulk density, depth of soil, and area (IPCC 2006).

Therefore, SOC (t/ha) = [Soil mass in 0–30 cm layer SOC concentration (%)] / 100

Total carbon stock density

The carbon stock density was calculated by summing the carbon stock densities of individual carbon pools of that stratum using the formula, as given below. It should be noted that any individual carbon pool of the given formula can be ignored if it does not contribute significantly to the total carbon stock.

$\Delta C = \Delta C_{AGB} + \Delta C_{BGB} + \Delta SOC$

where

C = Carbon stock density

C_{AGB} = Carbon in above-ground biomass

C_{BGB} = Carbon in below-ground biomass

SOC = Soil organic carbon

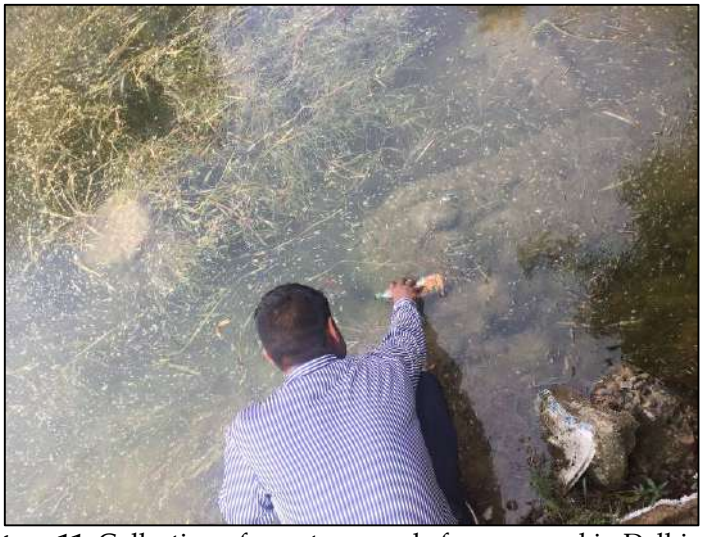
The total carbon stock is then converted to tonnes of CO_2 equivalent by multiplying it by 44/12 or 3.67 (Pearson, Brown, and Birdsey 2007).

Wetlands

Wetlands comprise 6% of the total area of the Delhi zoo. There are four artificial wetlands and one natural wetland. The methodology for the estimation of wetland carbon stock was developed through an extensive review of literature where relevant parameters and protocols were identified to estimate the carbon stock of wetlands. In the absence of any established method, the aquatic carbon methodology has been based on the information provided in the US Geological Survey report (Zhu 2010)[18]. The parameters considered for the estimation of carbon stock of wetlands were dissolved organic carbon, soil organic carbon, and emerged vegetation. All these three parameters were taken into consideration for natural wetlands, whereas only dissolved organic carbon and emerged vegetation were considered for carbon stock estimation of artificial wetlands.

Dissolved organic carbon

Water samples were collected from all the five wetlands from three different depths, 0.15 m, 1.0 m, and 2.0 m, using a standard penetration test (SPT) hammer sampler (IS: 9640, 1980). The water sample was then collected in a bottle and sent to the laboratory for analysis.



Picture 11: Collection of a water sample from a pond in Delhi zoo

Soil organic carbon

Two soil samples were collected from the natural wetland because the artificial wetland had no soil. The water sample was collected in the zipped pouches and sent to the laboratory for further analysis. The carbon stock density of soil organic carbon was calculated as (Pearson, Brown, and Birdsey 2007):

SOC = $rb \times d \times \%C$

where

[18] Zhu, Zhiliang, ed., B Bergamaschi, R Bernknopf, D Clow, D Dye, S Faulkner, W Forney, R Gleason, T Hawbaker, J Liu, S Liu, S Prisley, B Reed, M Reeves, M Rollins, B Sleeter, T Sohl, S Stackpoole, S Stehman, R Striegl, A Wein, and Z Zhu. 2010. A method for assessing carbon stocks, carbon sequestration, and greenhouse-gas fluxes in ecosystems of the United States under present conditions and future scenarios, *US Geological Survey Scientific Investigations Report 2010–5233*, p 190

SOC = Soil organic carbon stock per unit area (t/ha)

r_b = Soil bulk density (g/cm^3) – Default value is 1.19

d = Total depth at which sample is taken (cm)

$\%C$ = Carbon concentration

Submerged vegetation

The fresh weight of submerged vegetation from all the wetlands was noted from 1 m × 1 m plot. The sample was then sent for drying to the laboratory and the dry weight was noted. The dry weight of emerged vegetation collected from 1 m^2 plot was used to extrapolate the biomass of the entire wetland.

Total biomass (kg/m^2) = Dry weight (kg) × Area (m^2)

C = Total dry weight × 0.47

Picture 12: Collection of vegetation from the wetland of Delhi zoo

After estimating the total carbon stock of the Delhi zoo, the carbon stock was then converted to carbon stock equivalent using a factor of 3.67. The total value of carbon storage was estimated using the social cost of carbon.

Methodology for Assessment of Carbon Sequestration of Forests, Wetlands, and Grasslands

To calculate the value of carbon sequestration, the mean annual sequestration rate for forests, wetlands, and grasslands was used. The total value of carbon sequestration was estimated using the social cost of carbon.

Value of carbon sequestration = Average annual carbon sequestration rate × Total area of ecosystems (Forest/Grassland/ Wetland) × Social cost of carbon

Value of Carbon Storage

Forests

The National Zoological Park comprises 72% of the forest area which equals 51.45 ha. In this study, the forest carbon stock was calculated in 19 sample plots of 0.1 ha each. The plots covered both the forests and the avenue plantation. The carbon stock values for all three-carbon pools — above-ground biomass, below-ground biomass, and soil organic carbon — were calculated. The resultant figures were extrapolated from a per plot basis to per hectare.

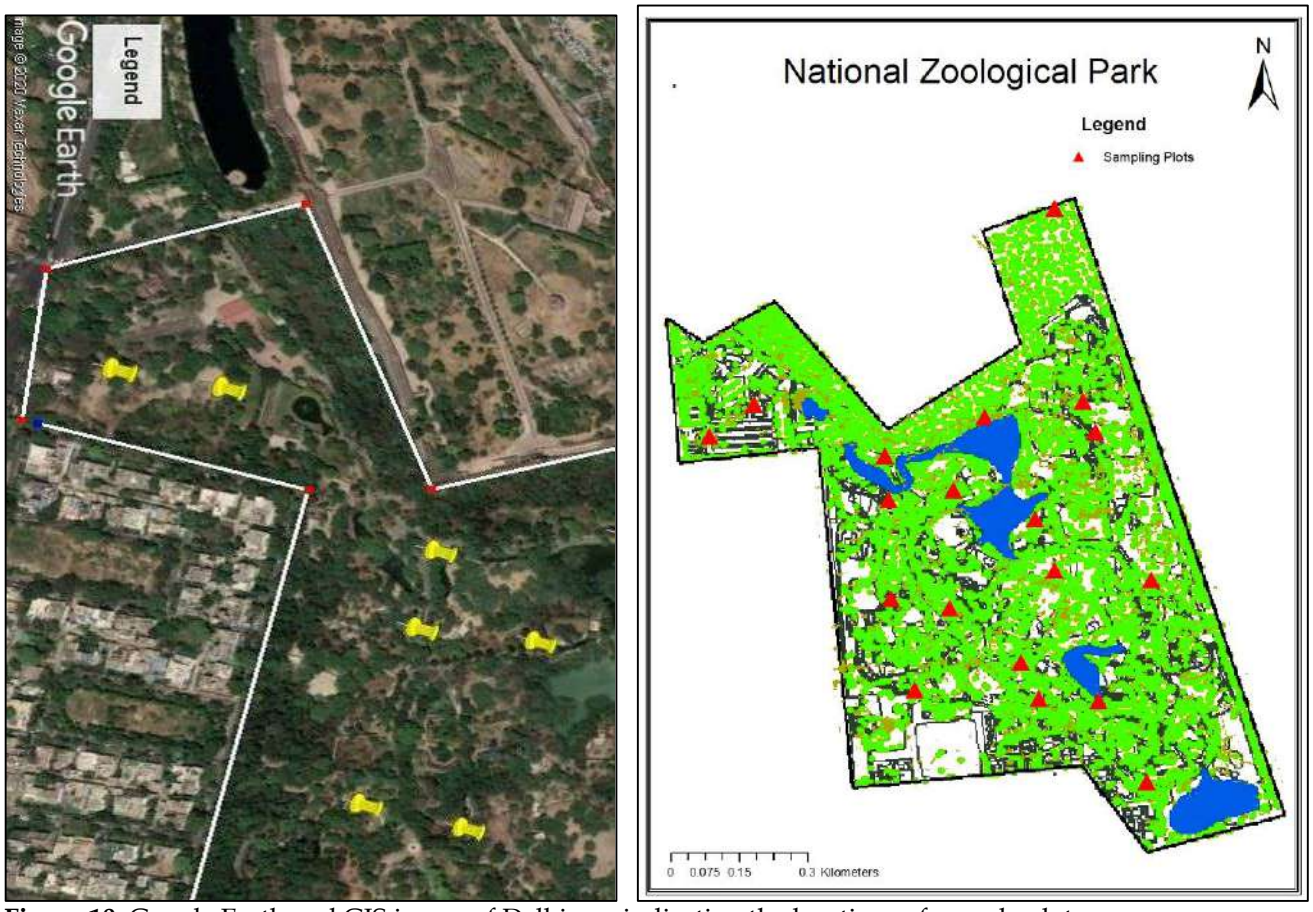


Figure 10: Google Earth and GIS image of Delhi zoo indicating the locations of sample plots

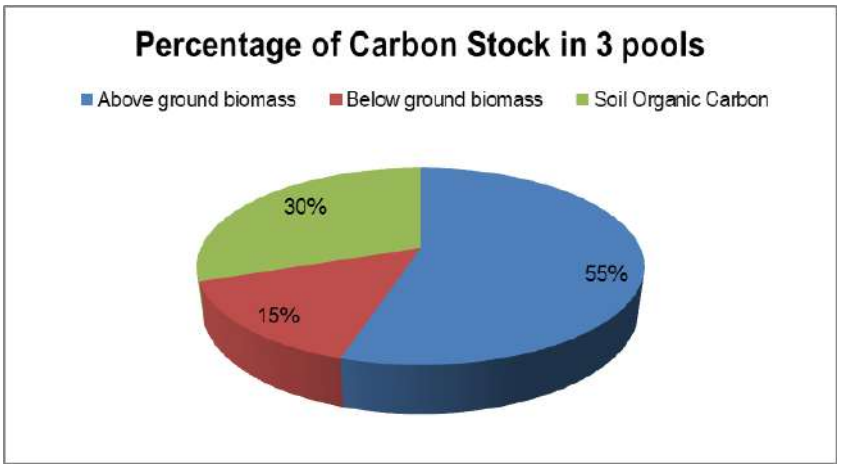
Source TERI

The total biomass in the forest ecosystem for the three pools of carbon – above-ground, below-ground, and soil organic carbon – was estimated to be 10,539.92 tonnes. The biomass of each carbon pool is given in Table 5.

Table 5: Biomass stock of forests

Stratum	Area (ha)	Above-ground biomass	Below-ground biomass	Biomass (in tonne)
Moderately dense forest	51.45	8299.15	2240.77	**10,539.92**

Figure 11: Percentage of carbon stock in three pools of forests



Based on the biomass content, the carbon stock for all the three pools in the forest ecosystem was calculated to be 7111.58 tonnes. The forest carbon stock and percentage of different pools are provided in Table 6 and Figure 11.

Table 6: Carbon stock of forests

Stratum	Area (ha)	Above-ground biomass	Below-ground biomass	Soil organic carbon	Carbon stock (in tonne)
Moderately dense forest	51.45	3900.60	1053.16	2157.81	**7111.58**

As calculated in the study, the highest percentage of carbon stock is present in above-ground biomass (55%) and soil content (30%) followed by below-ground biomass (15%).

Grasslands

Grasslands cover 9% of the total area of the Delhi zoo, which is 6.024 ha. The carbon stock values for all three eligible carbon pools — above-ground biomass, below-ground biomass, and soil organic carbon — were calculated. The biomass of grasslands was calculated to be 4.73 tonnes/ha and the total biomass for the two pools was calculated to be 29.33 tonnes (Table 7).

Table 7: Biomass stock of grasslands

Carbon pool	Biomass (tonne/ha)	Area (ha)	Biomass (in tonne)
Above-ground biomass	3.15	6.2	19.53
Below-ground biomass	1.58	6.2	9.80
Total	**4.73**		**29.33**

The total carbon stock was calculated to be 157.74 tonnes. Of the total carbon stock of grasslands, almost 91% of carbon was present in soil organic carbon while 6% was present in above-ground biomass and 3% was found in below-ground biomass (

Table 8 and Figure 12). This indicates rich carbon content in the grassland soil.

Table 8: Carbon stock of grasslands

Carbon pool	Carbon stock (tonne/ha)	Area (ha)	Carbon stock (in tonne)
Above-ground carbon	1.48	6.2	9.18
Below-ground carbon	0.74	6.2	4.60
Soil organic carbon	23.22	6.2	143.96
Total	**25.44**		**157.74**

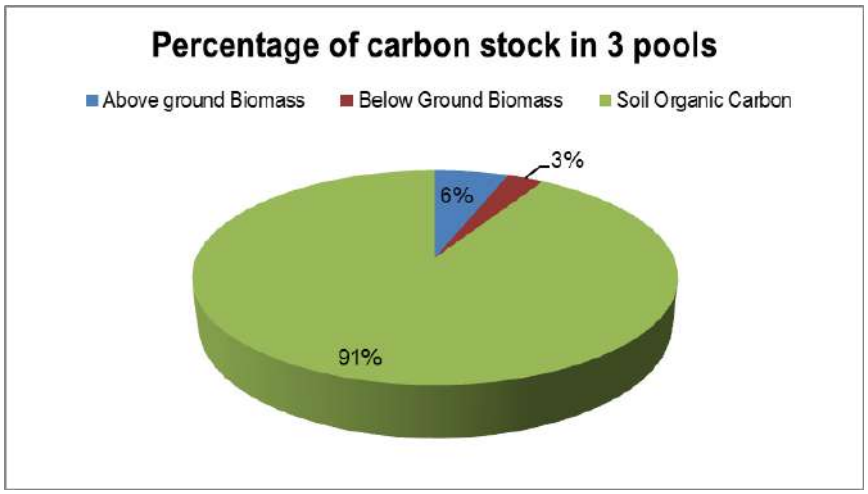


Figure 12: Percentage of carbon stock in different pools of grasslands

Wetlands

Wetlands cover 6% of the total Delhi zoo area, which is 4.148 ha area. The value of carbon stock was calculated after considering three parameters: dissolved organic carbon, soil organic carbon, and submerged vegetation. The total carbon stock of wetlands of the zoo was calculated to be 27.55 tonnes/ha and 65.74 tonnes (Table 9). Out of the total carbon stock of wetlands, 57% of carbon was present in soil organic carbon, 32% was present in vegetation, and 11% was found in dissolved organic carbon. **As there is only one natural wetland in the zoo, the soil organic carbon was tested only for one wetland and the results were not extrapolated to the total wetland area.**

Table 9: Carbon stock of wetland

Carbon pool	Carbon stock (tonne/ha)	Area (ha)	Carbon stock (in tonne)
Vegetation	5.13	4.14	21.25
Soil organic carbon	20.65	1.8	37.16
Dissolved organic carbon	1.77	4.14	7.33
Total	**27.55**		**65.74**

The total value of carbon storage

The total carbon stock of forests, grasslands, and wetlands is 7335.06 tonne. The total carbon stock was converted to tonnes of carbon equivalent using the factor 3.67 and the social cost of carbon (US$86) was applied. The US$ value was further converted to INR using a conversion rate of US$1 = INR 74.11.

The annual economic value of carbon storage service provided by the Delhi zoo is **INR 171,571,441** or **INR 17.15 crore**. The value of carbon storage being a one-time value has not been considered in the total economic valuation of the Delhi zoo.

Value of Carbon Sequestration

Forests

For this study, an average annual carbon sequestration rate of 10 tC/ha/yr was utilized for forests and extrapolated to the total forest area in the Delhi zoo. The total annual carbon stock was converted to tonnes of carbon equivalent using the factor 3.67 and the social cost of carbon (US$86)[19] was applied. The US$ value was further converted to INR using a conversion rate of US$1 = INR 74.11.

The annual economic value of carbon sequestration service provided by the forests of the Delhi zoo is **INR 12,034,463** or **INR 1.2 crore**.

Grasslands

For this study, an average annual carbon sequestration rate of 7.4 tC/ha/yr[20] was utilized for grasslands and extrapolated to the total grassland area in the Delhi zoo. The total annual carbon stock was converted to tonnes of carbon equivalent using the factor 3.67 and the social cost of carbon (US$86) was applied. The US$ value was further converted to INR using a conversion rate of US$1 = INR 74.11.

The annual economic value of carbon sequestration service provided by the grasslands of the Delhi zoo is **INR 1,042,004** or **INR 0.1 crore**.

[19] Ricke, K, L Drouet, K Caldeira, and M Tavoni. 2018. Country-level social cost of carbon. *Nature Clim Change* 8: 895–900

[20] Grace, J, J San Jose, P Meir, H Miranda, and R Montes. 2006. Productivity and carbon fluxes of tropical savannas. *Journal of Biogeography* 33(3): 387–400

Wetlands

For this study, an average annual carbon sequestration rate of 0.72 tC/ha/yr was utilized for wetlands and extrapolated to the total wetland area in the Delhi zoo. The total annual carbon stock was converted to tonnes of carbon equivalent using the factor 3.67 and the social cost of carbon (US$86) was applied. The US$ value was further converted to INR value using a conversion rate of US$1 = INR 74.11.

The annual economic value of carbon sequestration service provided by wetlands of Delhi zoo is **INR 69,891** or **INR 0.0069 crore**.

The total value of carbon sequestration

The annual economic value of carbon sequestration service provided by the Delhi zoo for 2019–20 is **INR 13,146,358** or **INR 1.31 crore**.

Recreational and Cultural

Introduction

The National Zoological Park is a famous destination on the tourism map of Delhi. Most of the national or foreign tourists who visit Delhi make it a point to visit the zoo, which is a 'must-see' place in the capital. Hundreds of tourists visit the zoo daily to view the animals and spend leisure time.

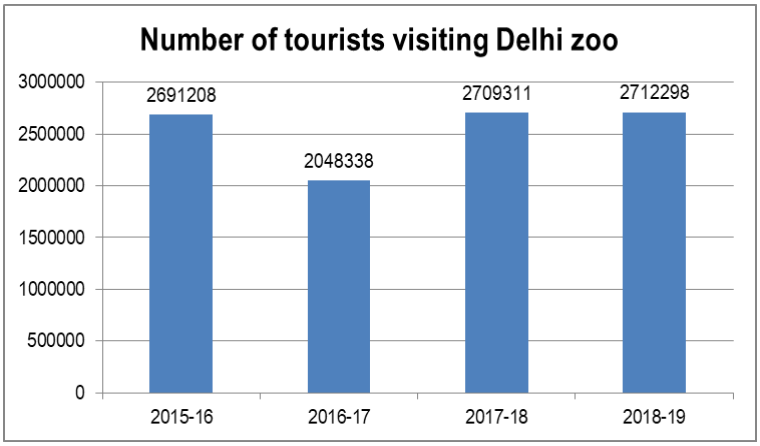


Figure 13: **Number of tourists visiting Delhi zoo over the years**

Source National Zoological Park

The number of tourists visiting the Delhi zoo has grown consistently over the years (Figure 13). In 2018–19, 19,568 foreign tourists and 2,692,730 domestic tourists visited the zoo. The entrance fee for foreign tourists is almost five times that of the national tourists (Figure 14).

ENTRANCE FEE (NORMAL)	
Adults	Rs. 40/- per head
Children (0-5 yrs)	Free
Children (5 -12yrs)	Rs. 20/- per head
Senior Citizen (60 Years and Above)	Rs. 20/- per head
ENTRANCE FEE (FOREIGNERS)	
Adults	Rs. 200/- per head
Children (Up to 5 Years)	Free
Children (5-12 Years.)	Rs. 100/- per head

Figure 14: Entry fees for domestic and foreign tourists at the Delhi zoo

Source National Zoological Park

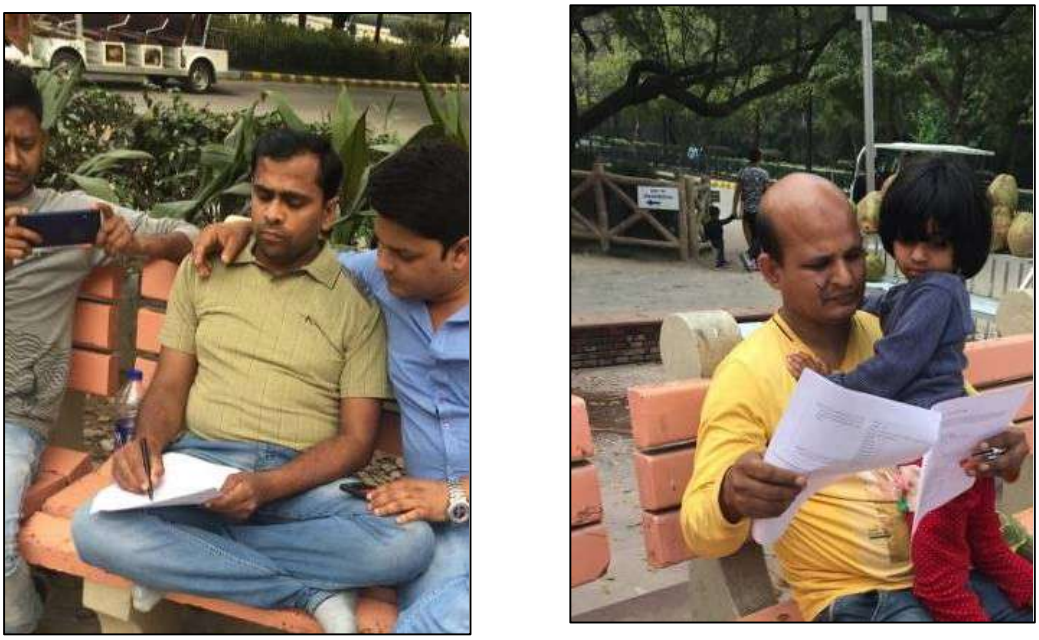
In addition to the entrance fee, tourists are also charged for their still and film cameras. The total revenue generated by the zoo in 2018–19 was INR 100,964,296.

As previously mentioned, the Delhi zoo is located on the periphery of the Old Fort. The view of the Fort in the background is a delight for tourists. The zoo is also surrounded by the ruins of Azimganj Sarai near Sunder Nursery, which adds a cultural flavor to the aura of the zoo, thereby enhancing its aesthetic beauty.

Methodology

The historical data of tourists (Indian and foreign nationals) visiting the National Zoological Park and the total revenue from 2011–12 to 2018–19 were analyzed. The primary data was collected through a questionnaire (Annexure 6) survey and the secondary data were collected from the records of the National Zoological Park. The informal interactions with the tourists suggested that most Indian tourists visiting the zoo were from Delhi, Rajasthan, Uttar Pradesh, Punjab, and Haryana. Tourists from beyond these areas were less frequent and could be thought of as yet another category. Using the latest data including the per day income of a tourist and expenditure incurred by the tourist on entry tickets, food and drinks, miscellaneous costs, the economic value of recreational services from the zoo was estimated.

The individual travel cost method (TCM) was used to estimate the value of tourism and recreational services. The TCM is based on the assumption that visitors value the experience of a particular site at no less than the cost of getting there, including all direct transport costs as well as opportunity costs of the travel time spent. So initially, a survey of the individuals was undertaken to determine the costs incurred in visiting the site. These costs included travel time, any financial expenditure involved in getting to and from the site, along with the entrance (and/or parking) fee. Additionally, information on the place of origin for the journey and basic socio-economic factors such as income and education of the individual was also documented. The survey was conducted through in-person interviews and email interactions.



Picture 13: Tourists filling up the survey forms on recreational and cultural services in Delhi zoo

Value of Recreational and Cultural Services

The number of visitors coming to the zoo has increased over the years with 20 lakh tourists visiting the zoo every year, on average. Costs incurred by tourists on their travel to the National Zoological Park from their homes (distance cost), along with the entrance fee, time spent, and other miscellaneous expenses have been taken into consideration when estimating the value of recreational services under TCM. The survey revealed that the average per day income of the tourists visiting the zoo is INR 655. The per-head average transportation (to and fro) cost from the pit stop to the Delhi zoo amounted to INR 428.

Similarly, other expenses incurred by tourists visiting the zoo – entrance fee, parking fee, food and drinks, and electric vehicles – totaled to INR 194 (Table 9).

Thus, after extrapolating the unit cost per tourist to the total zoo visitors, the annual economic value of recreational and cultural service for 2019–20 is estimated to be **INR 3,243,256,050** or **INR 324.33 crore**.

Table 9: Annual monetary value of tourism and recreational services

Parameter	Value per tourist (INR)	Total value (INR)
Per day income	654.87	1,663,568,041
Transportation cost (round-trip)	428	1,087,243,692
Other expenses (Entry fees + Parking + Food and drinks + Hawkers + Electric vehicles)	193.85	492,444,316.4
Total value		**3,243,256,050**

Source TERI survey

Picture 14: Tourists outside the ticket counter at National Zoological Park

Total Economic Value of National Zoological Park

The total economic value of the ecosystem services provided by the National Zoological Park includes both direct and indirect values which consist of provisioning, regulating, and supporting services. The total economic value of the National Zoological Park in terms of annual and one-time cost is given in Table 10 and Table 11.Table

Table 10: Total annual economic value provided by National Zoological Park

S. No.	Ecosystem service	Type of service	Valuation technique	Total value (INR) (crore/ year)	% contribution of total economic value
1.	Biodiversity conservation	Non-use value	Contingent valuation	27.33	6
2.	Employment generation	Direct-use value	Market price	32.19	8
3.	Education and research	Indirect-use value	Market price	37.6	9
4.	Carbon sequestration	Indirect-use value	Market price	1.31	0.31
5.	Recreational and cultural	Indirect-use value	Individual travel cost method	324.33	77
				422.76	**100**

The total annual economic value of the ecosystem services provided by the National Zoological Park for 2019–20 is estimated to be **INR 422.76 crore**.

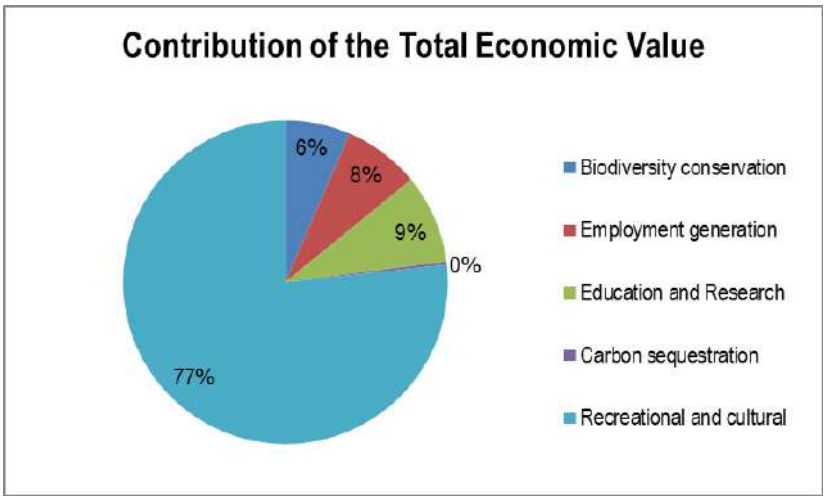


Figure 15: Contribution of the ecosystem services provided by National Zoological Park

Almost 77% of the contribution comes from recreational and cultural service which indicates the significance of this service to the zoo. Education and research, the next most important service, contributes 9% to the total economic value while employment generation contributes 8%. The contribution of biodiversity is 6% and carbon sequestration contributes only 0.31% to the total economic value.

Table 11: Total one-time cost of economic services and value of land for National Zoological Park

S. No	Ecosystem service	Type of service	Valuation technique	Total value (INR crore)
4.	Carbon storage*	Indirect-use value	Market price	17.15
5.	Surrogate value of land	Non-use value	Opportunity cost	25
6.	The land value of the Delhi zoo	Non-use value	Market price (benefit transfer)	55,167.30
				55,209.45

In terms of the one-time value of services provided by the zoo, the service of carbon storage is estimated to be INR 17.15 crore. The average land value of the Delhi zoo is estimated to be INR 55167.30 crore while the surrogate land value is estimated to be INR 25 crore.

Every service is important as it contributes to the improvement of the health of the local environment. The benefits of the zoo extend to both visitors and citizens of Delhi. Hence, the maintenance of the Delhi zoo must be prioritized to improve the services provided by it.

The study is based on the data collected for the year 2019-20 and hence should be considered as the baseline year. In case of need to use the valuation figure in the future, the values should be multiplied with the annual inflation rate and many years by using the compounding formula to assign the value for that particular year. The future value could be identified using the following formula as mentioned in the example provided below:

FV = PV * (1+i) n

Where, FV – Future value

PV – Present value/ discounted value

i – Inflation rate

n – Number of years

Inflation is measured using the Consumer Price Index (CPI). The inflation rate is the rate at which the general rise in the level of prices, goods, and services in an economy occurs and how it affects the cost of living of those living in a particular country. The inflation rate in India averaged 6.49 %from 2012 until 2018, reaching an all-time high of 12.17 % in November of 2013 and a record low of 1.54 % in June of 2017 (Trading Economics, 2018). Considering the above data, we have considered an average inflation rate of 6 % for 10 years.

Considering the amount of INR 8,80,000 is the fund required for action X. Here, one-tenth of the total fund required has been taken as the present value which is INR 88,000 and is also considered as the base amount for the first year.

Hence the future value at the end of tenth year will be:

Example: PV = 88000
I = 6% i.e. 6/100 = 0.06
n = 10 years
FV = PV $(1 + i)^n$
= 88000 $(1+0.06)^9$
= 88000 * 1.69
= 148674.148

Year	Present Value	Inflation rate	Future value
1	88000	-	88000
2	88000	1.06	93280
3	93280	1.06	98876.8
4	98876.8	1.06	104809.4
5	104809.4	1.06	111098
6	111098	1.06	117763.9
7	117763.9	1.06	124829.7
8	124829.7	1.06	132319.5
9	132319.5	1.06	140258.6
10	140258.6	1.06	148674.1
Total			**1159910**

Conclusion

The results of the total economic valuation of the National Zoological Park provide conservative estimates based on the primary and secondary data collected during the study. Although the zoo provides several other services, the study only takes into account the five key services based on the available resources. Even though the study is completely based on primary research, it is subject to several limitations.

Despite this, the study provides a powerful baseline assessment of the important ecosystem services provided by the zoo. The values these ecosystems encapsulate are very high, even though all the services were not possible to be evaluated. The total economic value of the five ecosystem services is estimated to be INR 422.76 crore and the main contribution comes from recreational and cultural services which were valued to be INR 324.33 crore, annually. This makes an important cause for the preservation of habitats such as the Delhi zoo in contributing to local, national, and global values.

This study is a 'first of its kind' for habitats such as the zoological parks in India. More such studies must be replicated across the country to understand the value of zoos. Currently, there are 160 zoos in India which include 17 in the large category, 25 in medium, 35 in small, and 85 in the mini category apart from rescue centers[21]. Such studies should be mandated at least for large- and medium-category zoos to understand their significance in terms of providing ecosystem services.

[21] Details available http://cza.nic.in/uploads/documents/reports/english/ar2017-18.pdf

Annexures

Annexure 1: Questionnaire for Biodiversity Conservation

We are surveying to understand the economic value of the ecosystem services provided by the Delhi zoo and would your valuable feedback. A brief background about the Delhi zoo is given below:

The National Zoological Park or Delhi zoo was established in 1959 with the purpose to showcase the animals in their natural habitat. The primary objective of the park is to impart awareness about wild animals and their habitats to the visitors. The park is spread across an area of 188.62 acres and represents a natural forest. There are 124 species of trees documented inside the park and several species of animals such as Palm Civet, Porcupine, Mongoose, Five Striped Squirrel, and Bats and birds of almost 76 species live here. In addition to the free-ranging animals, the park has around 124 species of animals in different enclosures.

Thus, the zoo provides not only a display of animals but also several ecosystem services such as biodiversity conservation, education and research, recreational and cultural, and employment generation.

ABOUT THE RESPONDENT

(1) Date _____

(2) Name and age of the respondent _____

_____

(3) Sex _____

(4) Occupation _____

(5) Contact details _____

SOCIO-ECONOMIC STATUS OF THE RESPONDENT

(6) What is your educational qualification?

a) Lower Primary b) Upper Primary c) Higher Secondary d) > Higher Secondary

(7) How long have you been living in Delhi?

a) 1–5 years b) 5–10 years c) 10–15 years d) >15 years

e) Other area……

(8) Is this your first visit to the zoo?

a) Yes b) No If No, how many times have you been to the zoo? ……

(9) What kind of occupation are you in?

a) Business b) Job c) Self-employed d) Student

(10) What is your average monthly income (in INR)?

a) 1000–10,000 b) 10,000–50,000 c) 50,000–100,000 d) 100,000 and above

In case you are a student, how much is your monthly allowance? ……

PERCEPTION OF PEOPLE

(11) Do you think wildlife conservation is necessary? If yes, what are your reasons?

_____

_____

_____

If no, then what are your reasons?

_____

_____

(12) Did you like visiting the zoo?

a) Yes b) No

Which aspect of the zoo interests you most? ……

(13) Which animal did you like the most in the zoo and why?

……

(14) Have you visited any national park or sanctuary before?

a) Yes b) No

Name the national park you have visited ……

(15) According to you, who should be responsible for maintaining the zoo?

a) Government b) People c) Both people and government

(16) According to you, what are the benefits of having a zoo?

……

(17) According to you, how good is the maintenance of the zoo?

……

……

……..

(18) In a hypothetical situation, if the government requests the citizens to contribute towards the maintenance of the zoo, how much money are you willing to pay on an annual basis?

……

a) 0–1000 b) 1000–10,000 c) 10,000–50,000 d) 50,000–100,000 e) 100,000 and above

Annexure 2: Questionnaire for Surrogate Value of Land

1.1 BASIC INFORMATION

(i) Name and age of the respondent

(ii) Address

(iii) Date and time _____

(iv) Sex _____

(v) Occupation _____

(vi) Number of households _____

1.2 SOCIO-ECONOMIC STATUS OF THE RESPONDENT

i. How long have you been living in this area?

ii. Do you own a house in this area or is it a leased property?

Own house	Leased property

iii. What is the total land size under your ownership?

iv. At what price did you buy this land on which your house is constructed? (Price/sq. ft)

v. What were your reasons to buy the property/land in this area?

Nearness to Supreme Court	Delhi zoo	Other

vi. Are you willing to pay for the 'intrinsic value' of the Delhi zoo/supreme court?

Yes	No

vii. What do you think are the market conditions for the land prices in this colony?

Increasing price	Decreasing the price

viii. What do you think are the reasons for the fluctuation in the market price/land value change in this area?

ix. What are the redevelopments that you have observed in this area because of the Delhi zoo?

x. Do you observe a difference in your surroundings in comparison to other areas in Delhi because of the nearness to the Delhi zoo?

Yes	No

xi. What do you think is a significant reason behind the migration of people from the Sunder Nagar colony to other places over the years?

Annexure 3: Questionnaire for Employment Generation

Q1. How many employees are working in the zoo?

Q2. How many of them are permanent and contractual (outsourced) employees?

Q3. What is the salary-wise segregation of employee data?

S. No.	Name/Type of post	Sanctioned	In position	Salary (pay scale) and allowance/year
1	*Director*			
2	*Veterinary doctor*			
3	*Record assistant*			
4	*Plumber*			
5	*Animal keeper*			

Q4. List the contract services and segregate services based on recurring and one-time costs of the zoo.

S. No.	Type of service	Cost (recurring or one time)	Amount (in lakh/INR)
1	*E.g. Feed and fodder*	Recurring	
2	*Operating theatre*	One-time cost	

Q5. Give the list of feed and fodder suppliers/vendors with recurring costs incurred.

S. No.	Type of feed and fodder supplier	Name/company of the vendor	The cost incurred/ year
1	*E.g. Meat, vegetables*		

Q6. Give the list of suppliers/vendors of medicines and other medical equipment with recurring costs incurred.

S. No.	Type of supplier	Name/company of the vendor	The cost incurred/ year
1	*E.g. Medicines, tranquilizing equipment, medical equipment such as stretchers, gloves*		

Q7. Give the list of service vendors for the maintenance of the zoo with recurring costs incurred.

S. No.	Type of maintenance service*	Name/company of the vendor	The cost incurred/ year
1			
2			
3			

** Maintenance service could be related to the maintenance of animal enclosures, seasonal arrangements, visitors' facilities, roads/paths, signages, paints, landscapes, maintenance of water pipelines, pumps, drains and filters, electrical points, zoo vehicles, feed stores, hospitals, offices, staff quarters and other buildings, CCTV and security services, etc.*

Q8. Give the list of additional services within the zoo with recurring costs incurred.

S. No.	Additional service	Additional staff involved (other than listed in Q2 and Q3)	The cost incurred/ year
1	*E.g. Refreshment outlets*		
2	*Restaurants (inside zoo)*		
3	*ATMs*		
4	*Cloakrooms*		
5	*Battery-operated vehicles*		
6	*Parking lot*		

Q9. Give details of permanent/temporary shops/stalls outside the zoo.

S. No.	Type of shop/stall	Number of people employed	Revenue generated per year	Profit generated per year
1	*E.g. Tea stalls*	1		
2	*Eateries*			
3	*Book stalls*			

Q10. Give details of permanent transport operating outside the zoo.

S. No.	Type of transport	Number of people employed	Revenue generated per year	Profit generated per year
1	*E.g. Autorickshaws*	1		
2	*Electric autorickshaws*			
3	*Mini-buses/vans*			

Q11. Give details of hawkers/sellers/other small businesses operating inside/ outside the zoo.

S. No.	Type of business	Number of people employed	Revenue generated per year	Profit generated per year
1	*E.g. Ice cream sellers*			
2	*Toys and souvenirs*			
3	*Snacks*			
4	*Other*			

Annexure 4: Questionnaire for Education and Research

We are surveying to understand the economic value of the ecosystem services provided by the Delhi zoo and would require your valuable feedback. A brief background of the Delhi zoo is given below:

The National Zoological Park or Delhi zoo was established in 1959 with the purpose to showcase the animals in their natural habitat. The primary objective of the park is to impart awareness about wild animals and their habitat to the visitors. The park is spread across an area of 176 acres and represents a natural forest. There are 124 species of trees documented inside the park and several free-ranging species of animals such as the Palm Civet, Porcupine, Mongoose, Five Striped Squirrel, and Bats and birds of almost 76 species. In addition to the free-ranging animals, the park has around 124 species of animals in different enclosures.

Thus the zoo provides not only a display of animals but also several ecosystem services such as biodiversity conservation, education and research, recreation and cultural, employment generation. Hence we would request you to please fill-up the questionnaire to understand your perception about the zoo.

BASIC INFORMATION

(i) Name and age of the respondent:_____

(ii) Address: _____

(iii) Date and time: _____

(iv) Sex: _____

(v) Occupation: _____

Students/Visitors

S. No	Questions	Response
1	How many times do you visit the zoo?	
2	How much do you pay as a school/tuition fee for a similar study?	
3	How do you value this experience on a scale of 1–10?	
4	What is the monthly subscription amount for various channels which provide knowledge on wildlife-related topics, e.g. National Geographic, Discovery?	
5	What is the annual average expenditure committed on purchasing literature on wildlife education by the household?	
6	What is the expenditure committed on visit nature reserves after visiting the zoo for real-time experience of wildlife watching in the last two years?	
7	Any other specific expenditure committed annually or in the last two years specific to education or research on wildlife?	

Annexure 5: Data-entry Sheet for Carbon Sequestration and Storage

DETAILS OF QUADRAT						
Quadrat Number:						
Size of Quadrat (m): 31.62 m × 31.62 m						
GPS Reading	**S. No.**	**Lat. /Long.**	**Degree (°)**	**Minute (′)**	**Second (″)**	**Alt. (m)**
Corners	**1**	Latitude (N)				
		Longitude (E)				
	2	Latitude (N)				
		Longitude (E)				
	3	Latitude (N)				
		Longitude (E)				
	4	Latitude (N)				
		Longitude (E)				
Centre	**5**	Latitude (N)				
		Longitude (E)				

DATA COLLECTED BY:								
Name:								
Designation:								
Mobile Number:								
1. FORMAT FOR DATA COLLECTION OF TREES								
S. No.	**Species Name**		**Height (m)**			**Eye height (m)**	**GBH (cm) at 1.37 m from the ground**	**Remarks (physical attributes)**
	Common	**Scientific**	**Tree top (%)**	**Base of trunk (%)**	**Distance (m)**			

2. FORMAT FOR DATA COLLECTION OF SOIL ORGANIC CARBON			
Quadrat number:			
Quadrat size: 1 m × 1 m			
Soil depth	Soil sample (√Tick Mark) (~200 g)		Remarks (if any)
	Quadrat 1	Quadrat 2	
30 cm			

Annexure 6: Questionnaire for Recreational and Cultural Services

INTRODUCTION

This case study is part of a larger study being conducted by TERI on 'The economic valuation of Delhi zoo', supported by the National Zoological Park, India. We assure you that all the information collected for this survey is required for research purposes only and no part of this information will be used for any other purpose. Your feedback is important for the completion of our survey.

PART I: Respondent details

1) Date of Interview	
2) Time of Interview	
3) Name	
4) Age	(1) <18 (2) 18–25 (3) 25–40 (4) 40–60 (5) >60
5) Gender	(1) Male (2) Female
6) Contact No/(Email Id)	
7) Residential Address	
8) Nationality	
9) State	
10) Highest Level of Education	(1) Primary School (1st–5th std) (2) Middle School (6th–8th std) (3) Secondary School (9th–10th std) (4) High School (11th–12th std) (5) Graduate (6) Post Graduate (7) Other Professional Course
11) Occupation	(1) Student (2) Government employee (3) Private employee (4) Business (5) Farmer (6) Artisan (7) Construction worker (8) Domestic worker (9) Barber (10) Vendor (11) Driver (12) Fisherman (13) Retired (14) Unemployed

	(15) Others (Please Specify)
12) Annual Income (INR)	(1) < 20000 (2) 20000–40000 (3) 40000–60000 (4) 60000–100000 (5) 100000–300000 (6) 300000–600000 (7) 600000–900000 (8) > 900000

PART II: Information related to travel cost method

13) What was the city and district of departure from which you made this trip to the zoo?	
14) What were the means of transport used to travel to the zoo?	(1) Metro (2) Bus (3) Autorickshaw (4) Bike/Scooter (5) Own vehicle (6) Hired taxi (7) On foot (8) Government-operated tour bus (HOHO) (9) Rickshaw (10) Others (please specify)
15) How much time did you take to reach the zoo?	(1) <1 hour (2) 1–2 hours (3) 2–3 hours (4) 3–4 hours (5) >4 hours
16) Are you visiting in any group?	1) Yes (2) No
17) Group information	(1) Friends (2) Family (3) Colleagues (4) Students (5) Others (please specify) Number of people in each group (1) 2–6 (2) 6–12 (3) 12–20 (4) >20
18) Is there any person (dependent) traveling with you for whom you will cover the expenses? If yes, state the number	(1) Yes (2) No State the number of people dependent on you (1) 1–2

	(2) 3–4 (3) 4–6 (4) >6
19) What were the sources of information about the zoo?	(1) Television (2) Internet (3) Newspaper (4) Radio (5) Magazine (6) Friends/family/colleagues (7) Own experience (8) Others (Please specify)
20) What did the transportation cost?	(1) Fare from the locality of departure (public transport such as metro and bus) (2) Expenditure made on fuel (own vehicle) (3) Hired taxi fare (4) Autorickshaw fare (5) Government-operated tour bus (HOHO) fare (6) Rickshaw fare
21) What were the other expenses during your visit to the zoo?	1) Entry fee (inclusive of camera charges, if paid) 2) Food and drinks a) From zoo canteen b) From a restaurant outside the zoo c) From hawkers outside the zoo 3) Electric vehicle 4) Other expenses (please specify)
22) If outstation and on a trip to Delhi and other parts of India	(1) How did you reach Delhi? (i) Bus (ii) Car (own vehicle) (iii) Train (iv) Airplane (2) What was the transportation cost to reach Delhi? (i) Bus (ii) Car (own vehicle) in terms of fuel (iii) Train (iv) Airplane (4) What were the lodging charges? (5) If the fixed package was availed, what was the cost of the package? (6) Any other details, please specify
23) How many trips have you made to this zoo?	(1) (i) Once a year (ii) Twice a year (iii) Thrice a year (iv) Every alternate month (v) Once every month

	(2) If visited more than once, what is the preferred season/month of visit?
24) What is your primary reason to visit the zoo?	(1) To see animals (2) Research and education (3) Part of a longer trip with other destinations (4) Picnic (5) Cultural (6) Others (please specify)
25) How much time do you wish to spend within the zoo?	(1) <1 hour (2) 1–2 hours (3) 2–3 hours (4) 3–4 hours (5) >4 hours
26) How do you plan to spend the time at the zoo?	(1) Watching animals (2) Birdwatching (3) Research and education (4) Picnic (watching animals, exploring food options at the canteen) (5) Walking around the zoo
27) Is the zoo your only destination in the region? If no, please name other destination	(1) Yes (2) No If No, what are the other destinations? (1) Purana Qila (2) Humayun's Tomb (3) India Gate (4) Nizamuddin shrine (5) Nila Gumbad (6) Sabz Burz (7) Neeli Chhatri (8) Rock Edicts of Ashoka (9) Khairul Manzil Masjid (within the zoo) (10) Kos Minar (within the zoo) (11) Others (please specify)
28) For you, how important is a visit to the zoo compared to other things you might wish to explore in this area?	(1) Most important (2) Very important (3) Important (4) Somewhat important (5) Not that important

29) What is your most liked animal/bird in the zoo?	**Mammals** (1) Antelope (2) Himalayan Black Bear (3) Sloth Bear (4) Blackbuck (5) Jungle Cat (6) Deer (7) Elephant (8) Fox (9) Bison (10) Jackal (11) Langur (12) Leopard (13) Lion (14) Macaques (15) Rhinoceros (16) Bengal Tiger (17) Wolf (18) Hyena (19) Nilgai (20) Wild Boar (21) Baboon (22) Chimpanzee (23) Hippopotamus (24) Jaguar (25) Loris **Birds** (1) Hornbill (2) Peafowl (3) Pheasant (4) Shikra (5) Spoonbill (6) Vulture (7) Fowl Jungle (8) Heron Grey (9) Ibis White (10) Kite (11) Myna (12) Owl (13) Parakeet (14) Partridge (15) Pelican (16) Rhea (17) Stork (18) Budgerigar (19) Cassowary

	(20) Cockatiel (21) Cockatoo (22) Conure (23) Emu (24) Zebra Finch (25) Blue-and-Yellow Macaw (26) Munia (27) Ostrich (28) Parrot (29) Black Swan **Reptiles** (1) Cobra (2) Crocodile (3) Monitor Lizard (4) Python (5) Rat Snake (6) Sand Boa (7) Water Snake (8) Tortoise
30) What according to you is the reason behind the existence of zoos?	(1) Conservation of wildlife (2) Education and research (3) Tourist attraction (4) Others (please specify)
31) In your opinion, what improvements must be done to make the zoo more attractive and tourist-friendly?	(1) More clean and hygienic toilets (2) Better quality of cages for animals (3) More options for relaxation while moving around the zoo (4) Better facilities for differently-abled (5) More electric vehicles (6) More exotic species of animals and birds (7) More indigenous species of animals and birds (8) Facilities of the interpretation centre (9) Souvenir shops (10) Handy, informative, and easy-to-use guides and pamphlets (11) Better signages
32) Do you intend to visit the zoo more often if the facilities that you have described were introduced?	(1) Yes (2) No If No, why?
33) Do you find the entrance fee to the zoo reasonable?	(1) Yes (2) No
34) Are you willing to pay more towards the improvement of the quality and overall development of the zoo?	(1) Yes (2) No If Yes, how much are you willing to pay (in INR) for this purpose? (1) <50

	(2) 50–70 (3) 70–100 (4) 100–130 (5) 130–160 (6) 160–200 (7) 200–250 (8) >250
35) Will you recommend a friend, loved one, or relative to visit the zoo?	(1) Yes (2) No