Asian Journal of Conservation Biology, December 2020. Vol. 9 No. 2, pp. 298-303 AJCB: FP0147
ISSN 2278-7666 ©TCRP Foundation 2020

Simple spatial & statistical analytical techniques to aid wildlife management: a case of elephants in multiple use area of Uttar Kanada district, Karnataka, India

Chittaranjan Dave*

Government Science College, Gariyadhar, Gujarat- 364505, India

(Received: April 24, 2020; Revised: June 15, 2020; Accepted: November 20, 2020)

ABSTRACT

The available information hosted on the Western Ghat Spatial Data Infrastructure – an open-source database was used to showcase some simple yet useful spatial and statistical analysis tools for the wildlife managers away in the field with limited GIS and statistics capacity. In Indian scenario, the flagship species Asian Elephant (*Elephas maximus*) is an important subject for application of management efforts of landscape. Available data on elephant sighting as well as anthropogenic and landscape parameters were extracted. Elephants were found to be frequent in primary moist deciduous vegetation type ($\chi^2 = 12.62$, $p \leq 0.05$) with gentle to moderate undulation ($\chi^2 = 25.42$, $p \leq 0.01$). Elephants responded to anthropogenic structures like roads ($t = -3.36$, $p \leq 0.05$), human settlements ($t = -2.06$, $p \leq 0.05$) and agriculture tanks ($t = -2.18$, $p \leq 0.05$) The current work is not intended to arrive at any conclusion on elephant ecology or behaviour but to showcase how open-source data and tools can help wildlife managers in assessing the animal distribution pattern and animal response to various environmental and anthropogenic factors.

Key words: Habitat use, Open-source Database, Quantum GIS, Tropical Forest, Western Ghat

INTRODUCTION

Wildlife managers across the globe are intrigued by questions such as where, why and how animals occupy a landscape (Leopold, 1935). With the advance of methods and technologies such as telemetry, radio tagging, camera traps, remote sensing and geoinformatics in ecology and conservation, wildlife management in India has also benefitted in recent times as a by-product of ecological research (Schaller, 1967; Green 1986; Sukumar, 1989; Jhala, 1993; Karanth, 1995). In most cases, researchers are focussed on long term conservation of either a species or group of species or investigating ecological aspects to test predictions on intriguing natural phenomena (Jayapal *et al*. 2009; Dave & Jhala, 2011). Such research programs ultimately provide critical inputs for the management of wildlife in the region. However, due to complexity of analytical processes and underlying scientific assumptions, it becomes cumbersome for wildlife managers to replicate such experiments in other areas.

Recent revolution in informatics and digital data clouds have opened up various spatial and ecological datasets accessible to everyone. There are many dynamic open-source digital data repositories which are constantly being enriched by data exchange and updates. Most such online cloud-based data sources are either, created and maintained by government agencies or by international collaboration (eg. The US Federal Data Committee, National Spatial Data Initiative -USA, European Umbrella Organization for Geographic Information, National Informatics Centre, Govt of India, https://bhuvan.nrsc.gov.in) or by citizen science programs (see Devictor *et al*. 2010). Such repositories include data on various aspects of science and humanity like human demography, disease, epidemics, socioeconomics, biodiversity, natural calamity, climate and weather, culture and ethnicity, etc. Despite such available datasets and open-source technologies, very little is used directly by the field staff of the forest and other government enforcement and action implementation agencies.

The present study aimed at demonstrating and showcasing the use of open source database and technologies to arrive at quick decision on immediate management interventions by the field wildlife officials. For this study, Asian elephant (*Elephas maximus*) in the human dominated landscape of the Western Ghat was chosen. Asian elephant (*Elephas maximus*) is the largest terrestrial mammal and a flagship species of Indian forests distributed over wide vegetation types in India (Sukumar, 2006). Historically, Asian elephants were believed to be widely distributed - from Tigris - Euphrates in West Asia eastward through Persia into the Indian sub-continent, South and Southeast Asia including Sri Lanka, Java, Sumatra, Borneo and up to North China (Olivier, 1978; Sukumar, 2006). However, this former range which once covered over 9,000,000 km², has now shrunk to 486,800 km² (Sukumar, 2006). Out of this, the current elephant distribution in India is spread over around 110000 km^2 (about 3.5%) of its former range (Baskaran *et al*. 2011). To conserve and protect the species, Government of India has formally notified 28 Elephant Reserves (ERs) extending over about 61830.08 km^2, which was later supplemented by two more elephant reserves in 2012 namely, Khasi Elephant Reserve in Meghalaya and Dandeli Elephant Reserve in Karnataka (Anonymous, 2012).

*Corresponding Author's E-mail: chitranjan.dave@gmail.com

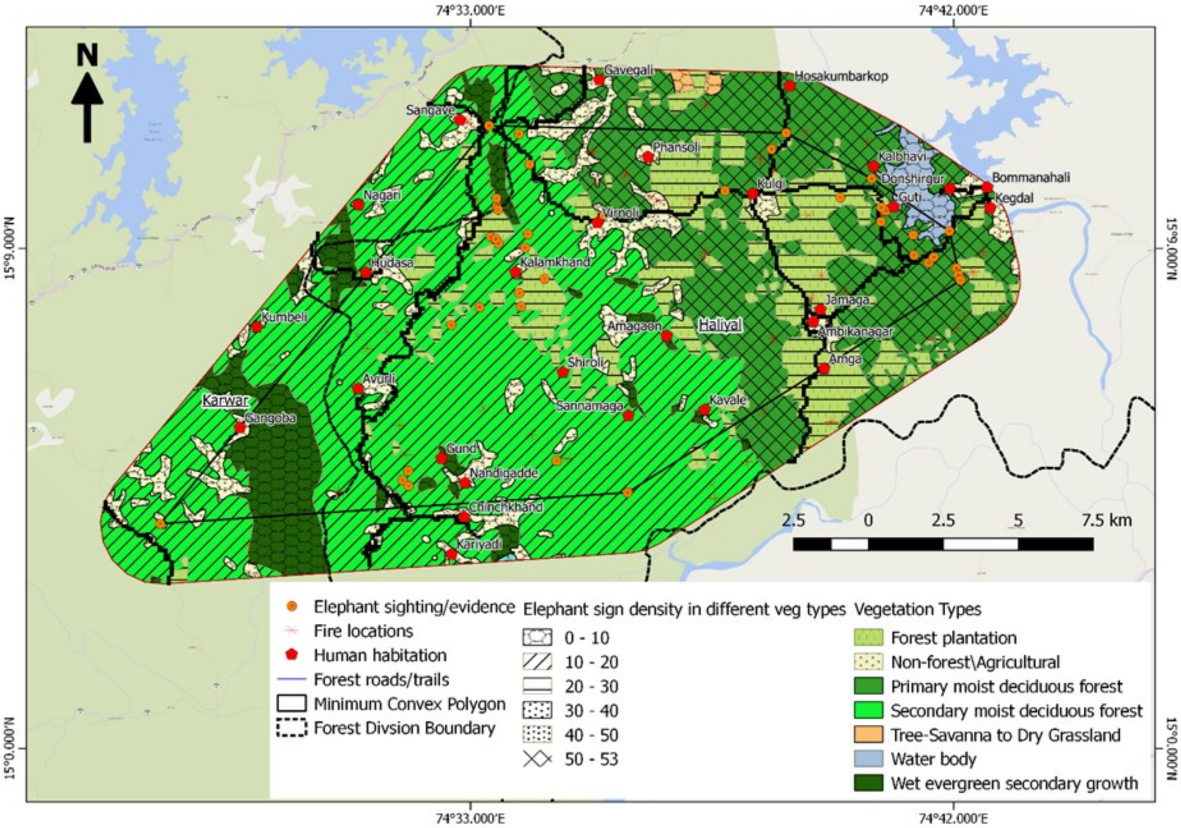

Figure 1. Geographic extent of the study area and locations of elephant evidence, human habitation, fire locations, administrative boundaries and roads plotted on land cover map prepared from WGSDI database. The map also shows the elephant sign density in various vegetation types of Western Ghat range in Uttara Kannada District, Karnataka.

The current range of the elephant population across India can be categorized based on their distribution over four forested landscapes i.e. (i) the foothills of Himalayas in the North (ii) the Northeastern states (iii) the forests of East-central India, and (iv) the forested hilly tracts of Western and Eastern Ghats in southern India. Among all four elephant populations in India, the elephant population of south India has been well studied and characterised better than those in other parts of the country (Krishnan, 1972; Nair & Gadgil, 1978; Nair *et al*. 1980; Sukumar, 1985). As per recent census report, around 14,000 elephants are found in southern India, with more than one-fourth of the habitat under Protected Area network (Baskaran *et al*. 2007). It is also evident from the past research that most of these Western Ghats sub population is growing and dispersing into neighbouring forests (Baskaran *et al*. 2011) and therefore this population has great conservation significance for the species in the wild. Since, the population and habitat of the Asian elephant is rapidly dwindling across the distribution range, it is imperative to analyse the key landscape level factors affecting the efforts to conserve such large-ranging animals like elephants and their habitats in human dominated landscape.

For this study few important management questions were considered as a set of study objectives which seem relevant and significant for any elephant range area:

(i) Whether elephants are randomly distributed in the area or follow some vegetation types and/or terrain structure?

(ii) Which of the vegetation type or land cover type is intensively used by elephants?

(iii) Do ecological or anthropogenic factors such as human settlements, roads, water-bodies and fire affect the elephant distribution pattern? If yes then which parameter has overriding effect on elephant distribution?

To address these objective questions two broad null hypothesis were proposed for statistical tests: 1) elephants are randomly distributed across the different land use/cover types and terrain ruggedness types; 2) Anthropogenic structures such as human habitations, roads, fire and water-bodies have no effect on elephant distribution.

Study area

The study area is located in the northern distribution range of the Asian elephant in the Western Ghats (15^0 02' N 74^0 25' E, 15^0 12' N 74^0 43' E (Figure 1). The Uttara Kannada district of Karnataka is located on the west coast of India with high rainfall (283.5 cm per annum) and warm weather with 20 ^{0} C. (mean winter temperature) to 33 ^{0} C. (mean summer temperature) (https://en.climate-data.org). This multiple use area is spread across the forested landscape of 28 villages in Uttar Kannada district of the state of Karnataka which lies within 10 km radius of the newly declared Anshi Dandeli Tiger Reserve and Dandeli Elephant Reserve. The study area covers the part of the Northern most distribution range of the Asian elephant which comprises different types of forests and human use areas over gently undulating to steep hilly terrain (WGSDI database (*https://www.kaiinos.com/wgsdi/*): Figure 1). The area is also rich in minerals such as manganese and iron ore as there are several operational mines in neighbouring area which affects the health of forests due to increased human presence and overall anthropogenic pressure which could have been a cause of extensive human-elephant conflict in the area. The area of interest (AOI) within this broad study area was identified based on the spread of direct and indirect evidences of elephant gathered by different volunteers and availed same to the WGSDI database. The AOI covered 349.17 km^2 area of 28 human settlements and part of back waters of Bommanhalli reservoir.

MATERIALS AND METHODS

The present study aimed to showcase the basic GIS operations using open-source databases in Quantum GIS 2.12 and 2.14 software (https://www.qgis.org/en/site/). Freely available open-source spatial vector data from Western Ghat Spatial Data Infrastructure (WGSDI) portal were used such as direct and indirect evidence locations of elephants, fire locations from 2008 to 2010, vegetation cover map of the area (1:25000), and boundary maps of the water bodies. The locations of all the human settlements and roads were digitized from the 'Open Street map' using open layer plugins in Quantum GIS ver. 2.12.1. For terrain model, Shuttle Radar Topography Mission (SRTM) imageries were used as raster data.

Forty-one point locations of direct and indirect elephant evidences from the WGSDI web portal were used. A distance matrix was calculated for these elephant locations. To determine the extent of AOI the average minimum distance calculated from the distance matrix (using 'analysis tool' under vector menu) was used to create a 2 km buffer over the minimum convex polygon. This was necessary to include all possible habitats of the elephants without being abrupt in mapping study area or the area of interest (AOI) (Figure 1). Once the area of interest was defined subsequently all the vector layers (Land use-Land cover LULC (polygon data), forest fire locations (point data), human habitations (point data), and roads (line data)) from the WGSDI database were cropped for the AOI using the 'Intersection' – a vector operation in QGIS. To visualize where exactly the AOI lies on physical and administrative map of the region using 'OpenLayer' plugin in 'web' menu, AOI was overlaid on online web map. Also this exercise helps in plotting some missing important landmarks and topographic features on existing vector layers at finer resolution. Then, the raster data in the form of a satellite imagery, (here in this case was SRTM data) was cropped for the AOI using 'clipper' tool in raster menu. To create the 3D model of the terrain, a digital elevation model (DEM) or digital terrain model (DTM) was built and the terrain ruggedness index (TRI) was extracted using raster analysis tool in QGIS. Once all the vector and raster data for the AOI is cleaned and compiled, further spatial data analysis could be carried out.

Spatial data analysis

Since the original data were in WGS84 coordinate reference system (CSR) which is generally used for the analysis of the landscape level data, were then transformed in to UTM 43N CRS for precise distance and area calculations for a smaller area.

Within the extent of this area, a set of random points (n=41, same number as actual elephant sighting locations) were generated to simulate the distribution of elephants as if they are randomly distributed over the AOI. The area calculation for each of the cover class in LULC vector layer was carried out. Subsequently, elephant locations and randomly generated points were overlaid on LULC map. (Figure 1).

The frequency of actual elephant evidences and random locations in each land use/cover type was calculated using 'point in polygon' function. The area under each of the land cover type was calculated using 'export/add geometry columns' function. The 'field calculator' in attribute table was used to calculate the density of the occurrences of actual elephant locations and randomly generated points. The density of elephant locations was calculated for each of the land cover types to visualize how elephants are using various land cover types. The attribute data were exported to spreadsheet for further statistical analysis using simple spreadsheet analysis functions.

DEM grid and 'Terrain Ruggedness Index (TRI)' was calculated from the SRTM imagery using 'raster analysis' tool. The point locations of elephant evidences as well as randomly generated (simulated random elephant locations) points were overlaid on the TRI grid. The TRI was categorized in to four classes as per the natural breaks in attribute using field calculator.

To assess the elephant response to burnt area, fire data for past five years which are available in WGSDI as well as Bhuvan web-portal (https://bhuvan.nrsc.gov.in) were plotted. The minimum distance from each of the actual elephant locations and random points were calculated to nearest fire locations, water-bodies, human settlements and roads using 'distance to nearest hub' tool in vector analysis tools. The attribute data of each of these vector layers were exported to spreadsheet for further statistical analysis to assess whether elephants are responding to environmental and anthropogenic disturbances.

Statistical analysis

Although there are ways to perform statistical analysis in QGIS with some available plugins and modules, here I exported the attributes table of the specific vector file as a spreadsheet for simple tabulation and basic statistical analysis to test the proposed hypotheses.

The frequency of occurrence of both i.e. actual elephant locations and random points in different land use classes were tabulated using 'points in polygon' analysis tool under vector menu and exported as a spreadsheet for *chi square* test in Excel workbook (MS Office 2016) for assessing the randomness of elephant occurrences over different vegetation types. Similarly, the frequency of occurrence of actual and random elephants in each of the four TRI classes were calculated and exported in a spreadsheet for further statistical assessment like chi-square and *t* test to test whether elephants are randomly distributed over different terrain ruggedness classes (Zar, 1999).

RESULTS

There were 41 actual direct and indirect elephant evidences over 349.17 km^2 area of multiple use forested landscape of Uttar Kannada district of Karnataka, India. The AOI is the part of Western Ghat landscape with rugged terrain and pockets of primary and secondary woodlands interspersed with patches of agriculture land. Classified land use and land cover vector file for the AOI had 8 land cover classes with the patches of secondary moist deciduous forest (162.43 km^2, 46.5 %) as main vegetation type in the area whereas wet evergreen primary forest is the least observed vegetation type (0.12 km^2, 0.04 %) (Table 1).

Actual elephant occurrence data and similar number of simulated random points were overlaid on land use land cover map. The frequency of occurrences of actual and simulated locations in each land cover class

Table 1. Area under different land use and land cover classes in the AOI

Sr. No.	Vegetation Type	Area of each land cover class	% of Total land cover	Actual elephant evidence	Simulated random location
1	Wet evergreen primary forest	0.12	0.04	0	0
2	Wet evergreen secondary forest	25.91	7.42	2	5
3	Secondary moist deciduous forest	162.43	46.52	13	21
4	Primary moist deciduous forest	80.83	23.15	16	8
5	Tree -Savanna toDry Grassland	0.85	0.24	0	0
6	Forest plantation	45.03	12.89	9	4
7	Non-forest\Agricultural	29.37	8.41	1	3
8	Water body	4.63	1.33	0	0
	Total AOI	349.17	100		

was calculated using the 'points in polygon' function in vector menu and exported to spreadsheet for subsequent statistical comparison (Table 1). The statistical test reveals that elephants are not randomly occurring over different vegetation types (χ^2= 12.62, p ≤ 0.05) (Figure 1). The results also indicate that elephants are not randomly occurring over different terrain ruggedness classes (χ^2 = 25.42, p ≤ 0.01) and they prefer gentle to moderate undulation (Figure 2) where almost 50% locations were found in 0 to 15 TRI only whereas in simulated scenario data spread is quite uniform. (Figure 2; 3a & 3b).

Mean minimum distance (in km) (± SE) from each of these elephant location to various ecological and anthropogenic factors such as roads (0.89 ± 0.16), human habitations (1.559 ± 1.35.8), waterbodies (7.01 ± 0.72) and fire locations (1.65 ± 0.14) were calculated to understand the behavioural response, if any. The Figure 3 shows the minimum distance depicted as lines from each of the actual as well as random elephant locations to nearest fire location. Similar measurement data were generated for other vector files as well i.e. to road, to water-bodies and to human habitation. Results indicate that elephants do not respond to the burnt areas (*t*= -0.14, p = 0.89) but have responded to roads (*t* = -3.36, p ≤ 0.05), human settlements (*t* = -2.06, p ≤ 0.05) and water-bodies (*t* = -2.18, p≤ 0.05).

DISCUSSION

The spatio-statistical analysis from the existing information it is evident that elephants respond to the environmental, topological and anthropogenic factors such as human settlements, water-bodies, roads and land cover

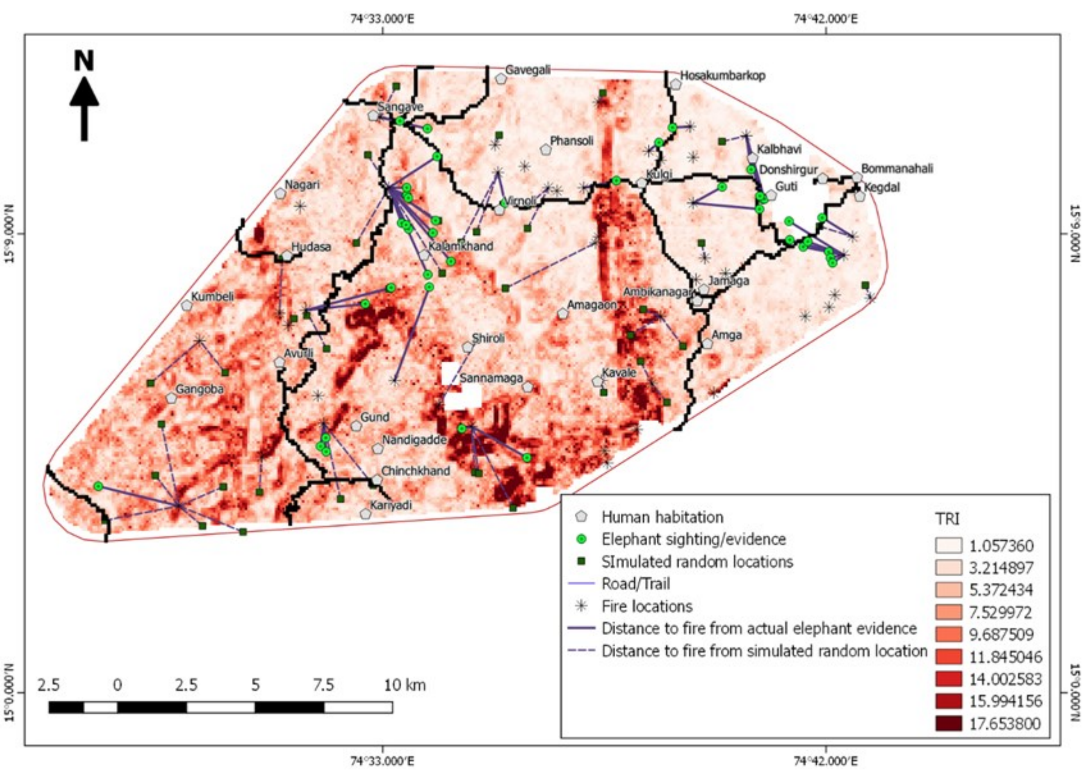

Figure 2. Actual as well as random elephant locations overlaid on digital elevation model using SRTM satellite data. The map also shows distance to fire location from actual and random elephant locations as simple and broken lines, respectively.

types (Sukumar, 1985). Elephants seem to be preferably using primary moist deciduous forests followed by secondary moist deciduous forest which is relatively disturbed and suboptimum habitat which are disturbed areas due to extensive human presence. When least disturbed habitats were scanty elephants switches to suboptimum habitat (Daniel, 1980; Rood *et al*. 2010). Most often this vegetation type occurs over gently undulating terrain to flat areas in vicinity to water bodies. This vegetation type also offers diverse and abundant foraging material to this large herbivore mammals (Gray & Phan 2011). For the conservation of the species it is desirable to maintain elephant habitat and reduce the human foot print over the landscape (Baskaran *et al*. 2011). Since, elephants tend to frequent in vicinity of human settlement area, appropriate conflict management measures needs to be planned for lowering community antagonism (Sukumar, 1989).

Since the fire locations were point locations and did not carry the information about the size of the burnt patch, elephant's response to fire was not discernible from the data as expected from previous study (Baxter & Getz, 2005). Secondly, the records of elephant locations were *ad libitum* sightings and indirect evidences gathered by different observers over a long stretch of period. In such condition data could be biases, as a) detection probability varies in different vegetation types (O'Connell *et al*. 2006) as well as chances of missing detection in low density population (Fitzpatrick *et al*. 2009) and, b) observers record all evidences along a road or trail while missing out evidences away from such road or trails.

With limited field data in quantity as well as quality, one could infer that elephants prefer to occupy habitats near water-bodies (Garcia *et al.* 2010) as these habitat may offer better forage and cover resources. Since these mega-herbivore species are living mostly in suboptimum habitat, they frequent human settlement areas in order to search of better foraging opportunities (Gaugris & Van Rooyen, 2010; Gray & Phan, 2011; Sukumar, 1989).

Scope of the present study was limited to showcase the simple ways of analysing spatial data using open source database (Western Ghat Spatial Data Infrastructure - WGSDI) and open-source GIS software (QGIS 2.12 & 2.14) for the field staff of forest department with limited expertise on statistics and GIS. There have been constant efforts in India to train wildlife managers to improve their technical skills in scientific decision making (Anonymous, 2019), however, very small proportion of the forest officials are able to use advance techniques in spatial and statistical analysis. One of the main reason seems to be the cost of the proprietary licenced software programs and hardware (Brovelli *et al*. 2017). Increased accessibility of open source data and easy to use as well as cost-free software programs have helped expand the user base in recent times across the field of diverse applications (Eng, 2005). Forestry and wildlife managers are in constant fight with threats and challenges of dynamic nature across the wilderness area of our planet. It is impractical to think of each forest official to be an expert in GIS and statistics and; also there are not enough resources to provide costly proprietary software to each forest ranger in the country. However, basic understanding of open-source data and a little know-how of simple spatial and statistical analysis can save time and resources. Therefore, this was an effort to demonstrate the simple use of GIS application in understanding wildlife distribution pattern in their habitat.

The current study has used the available location data of Asian elephants from the WGSDI for understanding how elephants are responding to various ecological and anthropogenic factors in suboptimum habitats. However, for any inference on the ecology and behaviour of the large mammalian species like elephants, it is strongly advised to have more rigorous data sets and analytical approach (Mcardle, 1990). Therefore, it is not wise to make any concluding remarks on the effect of various landscape features on such large ranging species from the present data analysis.

ACKNOWLEDGEMENT

I am grateful to OSGeo for providing travel and logistics support to attend the capacity building workshop for Western Ghat Biodiversity workshop at IIIT Hyderabad. I sincerely thank Dr. S. N. Prasad, R. C. Prasad and students of Lab for Spatial Informatics, IIIT Hyderabad for learning resources, necessary software and hardware.

REFERENCES

Anonymous. 2012. Introduction. Project Elephant. Ministry of Environment, Forest and Climate Change, Govt. of India. http://envfor.nic.in/division/introduction-4.

Anonymous. 2019. Annual Report 2018-19. Ministry of Environment, Forest & Climate Change, Government of India, New Delhi. 259pp.

http://moef.gov.in/wp-content/uploads/2019/08/Annual-Report-2018-19-English.pdf

Baskaran, N., Varma, S., Sar, C. K., & Sukumar, R. 2011. Current status of Asian elephants in India. *Gajah*, *35*, 47-54. https://pdfs.semanticscholar.org/ea4c/23e79647f92b7c1eeeced07bbd3bfc740bef.pdf?_ga=2.161815999.281020779.1587699092-955958520.1586584346

Baskaran. N., Kannan, G. & Sukukar, R. 2007. Southern India Elephant Census 2007. Report submitted to Karnataka State Forest Department. Asia Nature Conservation Foundation. Bengaluru. http://www.asiannature.org/sites/default/files/2007%20Synchronized%20Elephant%20Census%20KA%20Report.pdf

Baxter, P. W., & Getz, W. M. 2005. A model-framed evaluation of elephant effects on tree and fire dynamics in African savannas. *Ecological Applications*, *15*(4), 1331-1341.

https://www.academia.edu/26774367/A_Model-Framed_Evaluation_of_Elephant_Effects_on_Tree_and_Fire_Dynamics_in_African_Savannas

Brovelli, M. A., Minghini, M., Moreno-Sanchez, R. & Oliviera, R. 2017. Free and open source software for geospatial applications (FOSS4G) to support future earth. *International Journal of Digitial Earth*, 10(4): 386-404.

Daniel, J. C. 1980. The status of Asian Elephant in India. *Elephant*, 1(4): 16-28

Dave, C. V. & Jhala, Y. V. 2011. Is competition with livestock detrimental for native wild ungulates? A case study of chital (*Axis axis*) in Gir Forest, India. *Journal of Tropical Ecology*, 27(03), 239–247. https://doi.org/10.1017/S0266467410000738

Devictor, V., Whittaker, R. & Beltrame, C. 2010. Beyond scarcity: citizen science programmes as useful tools for conservation biogeography. *Biodiversity Viewpoint*, 16(3): 354-362. https://doi.org/10.1111/j.1472-4642.2009.00615.x

Eng, J. (Jr.). 2005. From software to life sciences: the spreading of the Open Source production to new technological areas. *Temple Journal of Environmental law*. 24: 419-438.

Fitzpatrick, M., Preisser, E., Ellison, A. & Elkinton, J. 2009. Observer bias and the detection of low density populations. *Ecological Applications*. 19 (7): 1673-1679. https://doi.org/10.1890/09-0265.1

Garcia, C. A., Bhagwat, S. A., Ghazoul, J., Nath, C. D., Nanaya, K. M., Kushalappa, C. G., & Vaast, P. 2010. Biodiversity conservation in agricultural landscapes: challenges and opportunities of coffee agroforests in the Western Ghats, India. *Conservation Biology*, *24*(2), 479-488. https://doi.org/10.1111/j.1523-1739.2009.01386.x

Gaugris, J. Y., & Van Rooyen, M. W. 2010. Effects of water dependence on the utilization pattern of woody vegetation by elephants in the Tembe Elephant Park, Maputaland, South Africa. *African Journal of Ecology*, *48*(1), 126-134.

Gray, T. N., & Phan, C. 2011. Habitat preferences and activity patterns of the larger mammal community in Phnom Prich Wildlife Sanctuary, Cambodia. *The Raffles Bulletin of Zoology*, *59*(2), 311-318. https://www.semanticscholar.org/paper/HABITAT-PREFERENCES-AND-ACTIVITY-PATTERNS-OF-THE-IN-Gray-Phan/69fcac7bcbac42e99f740bf26f43cdfb868ce9a7

Green, M. J. B. 1986. The distribution, status and conservation of the Himalayan musk deer *Moschus chrysogaster*. *Biological Conservation,* 35 (4), 347-375.

Jayapal, R. Qureshi, Q. & Chellam, R. 2009. Importance of forest structure versus floristics to composition of avian assemblages in tropical deciduous forests of Central Highlands, India. *Forest Ecology and Management*, 257 (11): 2287-2295.

Jhala, Y. V. 1993. Predation on blackbuck by wolves in Velavadar National Park, Gujarat, India. *Conservation Biology*, 7(4): 874-881. https://doi.org/10.1046/j.1523-1739.1993.740874.x

Karanth, K. U. 1995. Estimating tiger *Panthera tigris* populations from camera trap data using capture-recapture models. *Biological Conservation*, 71 (3): 333-338.

Krishnan, M. 1972. An ecological survey of the larger mammals of peninsular India: The Indian elephant. *Journal of Bombay Natural History Society.* 69, 469– 501. https://www.biodiversitylibrary.org/page/48288852#page/40/mode/1up

Leopold, A. 1933. Game Management. Charles Scribner's Sons, New York.

Mcardle, B. H. 1990. When are rare species not there? *Oikos*. 57:276-277. https://doi.org/10.2307/3565950

Nair P. and Gadgil M. 1978. The status and distribution of elephant populations of Karnataka. *Journal of Bombay Natural History Society*. 75 (Suppl):1000-1016 http://repository.ias.ac.in/64212/1/25-pub.pdf

Nair, P., Sukumar, R. and Gadgil M. 1980. The elephant in South India – A review. In The Status of the Asian Elephant in the Indian sub-continent, IUCN/SSC Report (ed) J. C. Daniel, Bombay Natural History Socienty, India.

O'Connell, A. F., Talancy, N. W., Bailey, L. Sauer, J. Cook, R. & Gilbert, T. 2006. Estimating site occupancy and detection probability parameters for Meso- and large mammals in a coastal ecosystem. *The Journal of Wildlife Management,* 70 (6): 1625-1633. https://doi.org/10.2193/0022-541X(2006)70[1625:ESOADP]2.0.CO;2

Olivier, R. 1978. Distribution and status of the Asian elephant. *Oryx*, 14(4): 379-424.

Rood, E., Ganie, A. & Nijman, V. 2010. Using presence-only modelling to predict Asian elephant habitat use in a tropical forest landscape: implications for conservation. Diversity and Distribution, 16(6), 975-894.

Schaller, G. 1967. The deer and the tiger: A study of wildlife in India. The University of Chicago Press, Chicago & London. 370p.

Sukumar, R. 1985. Ecology of the Asian Elephant (*Elephus maximum*) and it's interaction with man in South India. PhD Thesis, Indian Institute of Science, Banglore.

Sukumar, R. .1989. The Asian Elephant: Ecology and management. Cambridge University Press. 255p.

Sukumar, R. 1989. Ecology of the Asian elephant in southern India. I. Movement and habitat utilization patterns. *Journal of tropical Ecology*, *5*(01), 1-18. https://doi.org/10.1017/S0266467400003175

Sukumar, R. 2006. A brief review of the status distribution and biology of wild Asian elephants *Elephas maximus,* International Zoo Yearbook, 40 (2): 1-8.

Zar, J. H. 1999. *Biostatistical analysis.* 4th ed. Prentice Hall, New York.