Avens Publishing Group
J Environ Stud
September 2021 Vol.:7, Issue:1

Open Access Research Article

Journal of Environmental Studies

Assessment of Wildlife Habitats Using Geo-Spatial Techniques; Implications for Long-Term Habitat Management of Girnar Wildlife Sanctuary, Gujarat, India

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Submission: 01 August, 2021
Accepted: 05 September 2021
Published: 10 September 2021

Keywords: GIS; Greater Gir ecosystem; Hydrology; LST-NDVI relation; Habitat management

Abstract

Wildlife habitats are under significant threat due to rapid development activities. At present, remote sensing and GIS has been used widely for modelling, evaluating and monitoring wildlife habitats. These techniques have proven to be efficient tools for integrating the spatial and non-spatial data required for monitoring wildlife habitats. This study focuses on modelling the forest cover, assessing the hydrology and land surface features of the Girnar wildlife sanctuary using such geo-spatial techniques. The forest of Girnar is known for Asiatic lions, birds and its rich floral diversity, in which habitat characteristics and land surface features are poorly known. The spatial data from various Earth observation satellites were acquired, interpreted and analysed using different tools on the GIS platform to derive the hydrology, land use-land cover and land surface parameters of the sanctuary. Geo-spatial maps were prepared showing suitable forest cover, drainage pattern with respect to elevations, and the land surface temperature with respect to NDVI. The LST-NDVI plot shows the inverse correlation between the surface temperature and vegetation indicating the importance of dense vegetation in the dry deciduous forest. These deliverables will help policy makers in evaluating suitable habitats for Asiatic lion and its prey base in Girnar and formulating effective habitat enhancement and conservation strategies.

Introduction

Although renowned for its rich bio-resources in the present era, wildlife is vanishing rapidly in India due to growing influence of humans. The pressure of developmental activities and over exploitation of resources have been the prime causes for the decline of wildlife in almost all the countries [1,2]. Declaring National Parks and reserves are a dominant method for protection and conservation of remaining wildlife habitats and safeguarding resources like food, water, forest cover and corridors [3] however, these areas are not entirely ecological units or functional ecosystems in themselves, thus have experienced several management problems, like, general decline in plant and animal diversity leading to poor habitat conditions [4,5].

Wildlife management requires reliable and consistent information on the abundance, distribution of species and their habitats as well as threats. Management strategies have focused mainly on single species and protected areas. The need of developing integrated and advanced habitat evaluation and management techniques which can help in formulating long term conservation strategies have been previously identified [6,7]. These techniques also focuses on the maintenance of some desired state of the resource base within the reserve, while controlling the factors that negatively impacts habitat quality [8]. The quantification and analysis of current impacts on wildlife habitat such as logging, agriculture and road development are vital phases in the process of formulating sound wildlife management policies. Several ground-based studies and survey techniques such as counting animals, trapping, scat collection investigation of feeding sites as well as ground mapping of habitats [9-11] are fruitful.

Traditionally, large carnivore species have served as flagship and umbrella species for biodiversity conservation, worldwide. In Asia, lions have been driven almost to extinction, apart the only surviving free-ranging population of Asiatic lion (*Panthera leo persica*) is in and around the Gir forests of Gujarat, India [12]. From 1920 to present date, the current population has increased from 20 to 674 [13]. However their conservation is bristling with difficulties due to inhabitation at low densities, requirement of large areas, and often conflict with human through predation on livestock and sometimes on people [14,15].

The Girnar hills in Junagadh district of Gujarat, are famous since ancient times as a place of pilgrimage for both Hindus and Jains. The town of Junagadh is situated practically at the foothills of Mount Girnar, the highest peak in Gujarat state of India with the apex elevation of 1,069m. These hills lie between the parallels of latitude North 21^0 25' and 21^0 35' and meridians of longitude East 700 30' and 70^0 40' [16]. The aerial view of the Girnar resembles a circular disc of the diameter of 16km (Figure 1). Mount Girnar is a major igneous plutonic complex which intruded into the basalts towards the close of the Deccan Trap period [17,18]. The climate of Girnar is semi-arid with a mean temperature and mean annual precipitation of 25.7 ^{0}C and 827mm, respectively along with more than 800 species of plants and more than 200 faunal species. The Girnar forests is approximately 50km far from the Gir National Park and Wildlife Sanctuary. The area of 180km^2 of Girnar wildlife sanctuary (WLS) is now known as a part of greater Gir ecosystem constituted for the conservation of Asiatic lion. Once, the forests of Girnar were contiguous with the Gir forest, but gradually the urbanization and agricultural expansion have isolated these two forests converting Girnar as an isolated compact patch of forested habitat (Figure 2).

The topographic maps which are similar to any type of land cover mapping are hitherto being used by wildlife managers for formulating management plans in the sanctuary [19,20]. However, these ground surveys are limited, because it is difficult to access the entire area and the information collected may not be as accurate as is possible through remote sensing. Hence, it acts as a supplement or partially replaces these monotonous ground-based surveys. The geospatial technology such as Remote sensing and Geographical Information System (RS and GIS) play a key role in such situations and currently it is one of the quickest possible ways in deriving the environmental map layers to develop contemporary strategies for wildlife habitat assessment. This also has been used as a fundamental tool for getting information about the habitat preferences of wildlife species [21,22] and helps in monitoring areas of land that are suitable to endangered

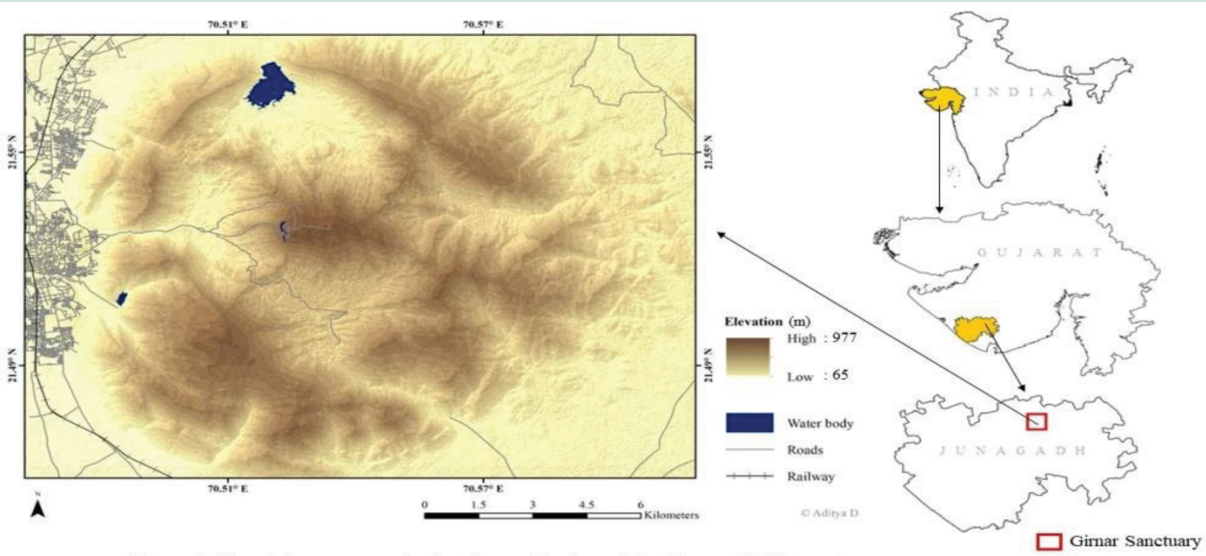

Figure 1: The study area overviewing the aerial view of the Girnar wildlife sanctuary.

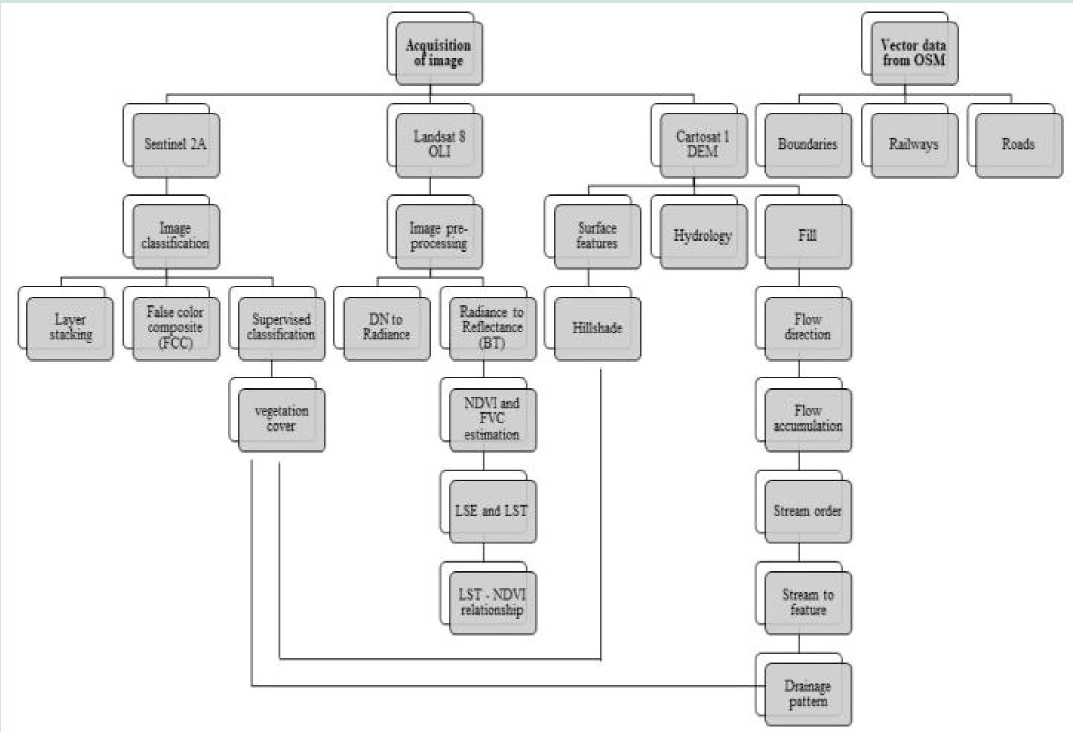

Figure 2: A flow chart illustrating the entire methodology.

ISSN: 2471-4879

species, through integration and interpretation of various habitat variables of both spatial and non-spatial nature [23].

Preparation of habitat management plans is one of the crucial management practices in the protect areas in India, which generally are prepared using the ground study and topographic maps. The intention behind the current study is to assist the forest managers to map the current vegetation cover of the wildlife habitat in Girnar Wildlife Sanctuary which serves as critical habitats for the Asiatic lion. The study also focuses on mapping of existing water channels which can help in planning the water conservation in the area. Remotely sensed spatial data of the sanctuary along with the land use layers, and Digital Elevation Models (DEMs) are also applied, interpreted and analysed on the GIS platform for habitat classification and water resource mapping which can be used as a base map for preparing management plan and formulating future conservation strategies in the Girnar wildlife sanctuary.

Materials and Methods

Data Sources

The satellite imagery of Sentinel-2A of the study area was acquired from Copernicus open access hub developed by the European Space Agency (ESA) https://scihub.copernicus.eu/dhus/#/home.The Cartosat-1 Digital Elevation Model (DEM) of Girnar wildlife sanctuary, was acquired fromIndian Space Research Organisation (ISRO)'s Geoportal Bhuvan, https://bhuvan-app3.nrsc.gov.in/data/download/index.php. It is an interactive versatile Earth-Browser which showcases multi-sensor, multi-platform and multi-temporal images with capabilities to overlay thematic information, interpreted from such imagery as a vector layer [24]. The acquisition of Landsat 8 OLI data was done using https://earthexplorer.usgs.gov. The United States Geological Survey (USGS) Earth Explorer data portal was used to obtain various earth imagery across available geo-spatial datasets [25,26]. Open Street Map (OSM) were also used to create a free editable map of the World https://www.openstreetmap.org/#map=15/24.4803/72.7920 & layers=N.In this study, several landuse layers such as roads, railways, built-ups, etc., were extracted along with the country and state boundaries of Gujarat and India from the OSM server and were digitized using ArcGIS tool [27,28].

Data analysis

Terrain and hydrology: The Digital Elevation Models (DEMs) are digital records of terrain elevations for ground position at regularly spaced intervals. The elevation values of terrain are valuable for modelling the terrain, drainage area, as well as studying the land use patterns [29]. It was used to compute the elevation range and to process several hydrological functions. At first, it was taken as an input raster to process the Fill tool, which resulted a depression less raster with all the sinks, filled. This output was taken as desired input raster to process the Flow Direction tool which generates the pixel value based on the flow path of water from higher elevation to lower elevation and also assigns a flow eight to each grid cell in the catchment, such that each grid cell tends to flow only in one of the eight neighbouring grid cells with the steepest slope [30,31]. It identifies all the sinks in the DEM and raises their elevation to the lowest level of pour point around their edge by using the eight directions pour point model. While running the flow direction algorithm, the resulting values ranged from 1, 2, 4, 8, 16, 32, 64, and 128 which describes all the adjacent eight directions at a given point. For processing the Flow Accumulation tool, the output rasters i.e., Fill and flow direction were taken as input rasters. Basically, in this sub-step, it calculates the total number of grid cells contributing to each grid cell in the catchment and assigns this value to this grid cell as flow accumulation [32,33]. After processing it, an algebraic expression was given to determine the threshold value while ordering the stream network, where flow accumulation = > 9500 which calculates all the respective streams and its branches in the output raster. Based on the above calculation, the calculated raster and flow direction raster were taken as input rasters and were processed using the Stream order tool where the ordering method STRAHLER was used [34]. This function based on the above user-defined threshold values of accumulation delineates the stream network for the catchment [35]. Lastly, the above output raster of stream order was converted into a vector layer by processing the tool, stream to feature. With this, the drainage pattern or the Streams were generated. The Hill shade tool along with slope and the aspect tool [36] was processed on the DEM to analyse surface features of the study area to correlate with the stream network from the highest to lowest elevation points.

Land Use Land Cover (LULC): The monitoring of vegetation is an accepted technique for habitat assessment. The sentinel 2A satellite consists of 13 bands in the visible, near infrared and short-wave infrared part of the spectrum which supplies multi-spectral data and a spatial resolution of 10, 20 and 60 m. Thus, it makes possible to figure out large amount of minute details of various ground features. In order to classify the image, the band composite function was processed for layer stacking to obtain a False Colour Composite (FCC). Maximum Likelihood Supervised Classification was performed in the Sentinel imagery and six different classes (i.e., water body, built ups, barren lands, open forests, moderate vegetation and dense vegetation) were differentiated based on the spectral signatures of each pixel. Maximum Likelihood Classification assumes the statistics in each class in each band are equally distributed and defines a specific class in which the given pixel value falls, where each pixel is assigned to the class that has highest probability (i.e., Maximum Likelihood). The area of each class was interpreted based on pixel count and resolution of cell. Other Land Use layers like roads, and railways were extracted from the open-source data repository, Open Street maps (OSM) which is used as a server and digitised in GIS environment through Web Mapping Services (WMS). A WMS defines an interface or a consortium that allows to get maps of geospatial data and can able to gain detailed information on specific features shown on the map. WMS can produce a map, as a picture, series of graphical elements or a set of geographic data. It also can answer basic queries about the content of the map.

Estimation of Land Surface Temperature (LST): The Landsat 8 OLI data was used to determine the Land Surface Temperature (LST) of the study area. It consists of two sensors OLI and Thermal Infrared Sensors (TIRs)in which OLI comprises of 8 bands located in the visible, near infrared and the short-wave infrared region of the spectrum which provides the data of 30 m spatial resolution. The TIRs senses the Thermal Infrared (TIR) radiance at a spatial resolution of 100 m with the help of two bands located in the atmospheric window between 10 and 12 μm [37]. For pre-processing the imagery, the first step is to convert the Digital Number (DN) values of band 10 to spectral radiance using the following equation:

$$L_\lambda = \left[\left(L_{max} - L_{min}\right) * Q_{cal} / Q_{calmax} - Q_{calmin}\right] + L_{min} - O_i$$

Where:

L $_{max}$ is the maximum radiance $\left(Wm^{-2}sr^{-1}\mu m^{-1}\right)$,

L $_{min}$ is the minimum radiance $\left(Wm^{-2}sr^{-1}\mu m^{-1}\right)$,

Q $_{cal}$ is the DN value of pixel,

Q $_{cal}$ max is the maximum DN value of pixels,

Q $_{cal}$ min is the minimum DN value of pixels, and

O $_i$ is the correction value for band 10.

After conversion of DN values to spectral radiance, the data is further converted to Brightness Temperature (BT) using the following equation:

$$BT = K2 / ln\left[\left(K1/L_\lambda\right) + 1\right] - 273.15$$

Where K1 and K2 are the thermal constants of TIR band, that can be identified in the metadata file associated with the satellite image. It is necessary to add absolute zero, which is approx. (–273.15)˚C to obtain the results in Degree Celsius. The required metadata of the satellite image is shown in Table 1.

In order to calculate the Fractional Vegetation Cover (FVC), the Normalised Difference Vegetation Index(NDVI) was calculated in the Landsat imagery which is necessary for further calculations of emissivity, and proportional vegetation. The NDVI is one of the most generally used indices for vegetation monitoring [38], as it quantifies the spatial distribution of vegetation biomass, hence, it is also said as 'Greenness Index' [39,40]. It is calculated as the normalised ratio between Red and near-infrared band data sensed by Landsat 8 satellite sensor. For calculating NDVI (Normalised Difference Vegetation Index), Band 5 and Band 4 which is Near Infrared and Red Band respectively, were processed.

$$NDVI = \lambda_{NIR} - \lambda_{RED} / \lambda_{NIR} + \lambda_{RED}$$

Where NIR = Band 5 and Red = Band 4 (Visible band)

the output raster resulted in ranges from –1 to +1 which depicts the characteristic features of pixel values of lower to higher vegetation. It is calculated as the normalised difference of the spectral reflectance of near infrared λ_{NIR} (0.85 μm) and Red λ_{RED} (0.67 μm). NDVI values vary between –1 and +1, and are undefined when both λ_{NIR} and λ_{RED} are zero [41]. For vegetated areas the values generally range from approximately 0.1 to 0.7, with values greater than 0.5 indicating dense vegetation and values less than 0.1 indicate no vegetation, e.g., barren area, rock, sand or snow [42].

Table 1: The metadata of Landsat 8 OLI consisting required constant values for calculations.

Constants	Value	Description
Oi	0.29	Correction value, Band 10
Qcalmax	65535	Maximum value of Qunatized calibration
Qcalmin	1	Minimum value of Qunatized calibration
k1 and k2	774.8853 and 1321.0789	Thermal constants, band 0
Lmax	22.0018	Maximum valuae of Radiance, Band 10
Lmin	0.10033	Minimum valua of Radiance, Band 10

The FVC is the ratio of the vertical projection area of vegetation (including leaves, stalks, and branches) on the ground to the total vegetation area which is calculated as per the formula:

$$FVC = \left[\left(NDVI - NDVI_{min}\right) / \left(NDVI_{max} - NDVI_{min}\right)\right]^2$$

Where, NDVI are the DN values from NDVI image, $NDVI_{min}$ are minimum DN values, $NDVI_{max}$ are maximum DN values.

Land Surface Emissivity (LSE) helps in reducing the Top of Atmospheric (TOA) Radiance in comparison with blackbody. It is defined as the ratio of the radiance emitted by an object to the radiance it would emit if it were a perfect black body at the same thermodynamic temperature [43]. It is calculated according to the formula:

$$LSE\ (\varepsilon) = 0.004 * FVC + 0.986$$

Where, FVC is the Fractional Vegetation Cover.

The LST is the radiative skin temperature of the land surface, as measured in the direction of the remote sensor, which is estimated from TOA brightness temperatures from the Thermal infrared spectral channels of geostationary satellites. Its estimation further depends on the albedo, the vegetation covers and the soil moisture [44].The vegetation and barren soil temperature, respond rapidly to the incoming solar radiation changes due to cloud cover, thus it is said as a mixture of both these parameters. The equation for calculating the Land Surface Temperature (ε) followed by Surface emissivity is as follows:

$$LST = \left[BT / \{1 + \left(0.00115 * BT / 1.4388\right) * Ln(\varepsilon)\}\right]$$

Where, BT is the Brightness Temperature and ε is the Surface Emissivity and Hence, by formulating these equations step-wise in the raster calculator, the LST of the study area was derived. Figure 3 shows a diagrammatic representation of the entire methodology.

Results and Discussions

Vegetation cover

The Land use Land Cover (LULC) classification shows a great significance in detecting regions that are covered by different type of vegetation and the land use in a particular area. Thus, LULC maps are the best source of information to the managers for understanding the landscape of any particular region. Figure 3, shows the LULC classification of the study area which comprises of 0.08% (0.19 sq.km) of Water body, 2 % (5.67 sq.km) of Built-up areas which are mostly the old temples and hermitage. However, there is no any new other development or built-up structure was recorded in the area. Further, the habitat of Girnar forest was classifiedas the forest area with moderate vegetation 35 % (117.89 sq.km), dense vegetation 8 % (26.1 sq.km), along with 26 % (88.15 sq.km) Grasslands, 30 % (101.78 sq.km) Shrublands and 1 % (1.76 sq.km) of Barren lands. Figure 4, depicts the forest areas with dense vegetation in the South-west direction with a high elevation and a slopy terrain, can be a suitable wildlife habitat. Generally, lions are considered as best example in predator-prey relationships as they usually hunt in groups and also pondered ambush predators, choosing prey catchability over

ISSN: 2471-4879

prey abundance and rely on concealment during hunting [45,46]. Therefore, dense vegetation enables the predators like lion and leopard to ambush their prey and also provides cover [47]. Thus, the areas in North-east, North-west and South-east needs to be afforested more to have a denser vegetation.

Hydrology

Water is said to be a most important driving factor in wildlife habitat and also acts as a source of life for all the animals. Figure 5 depicts five streams or water channels flowing from an elevation range of ~ 100 to 300m and also two of the five streams form the junctions at the reservoir at an elevation of 66 and 79m. Alongside, the majority of the dense forests is observed in these elevation range constituting a suitable wildlife habitat (Figure 4). Figure 5 depicts that all the streams in Girnar forest are of first order stream according to STRAHLER Order stream classifications, and are considered as primary or minor streams. These water channels flow and make their path in almost every direction from the origin point. As these are of

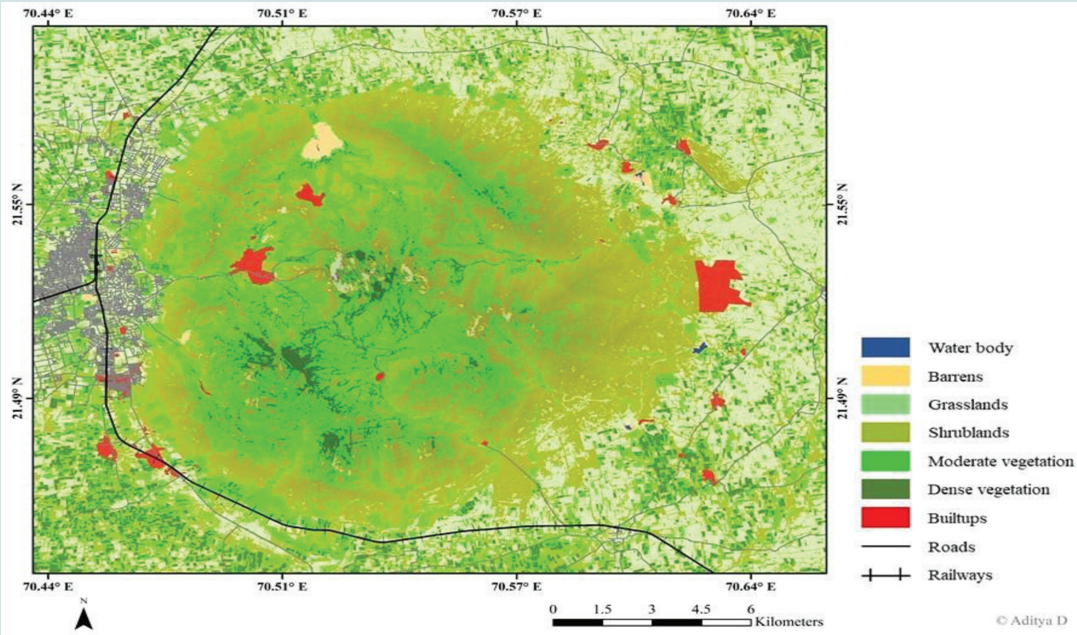

Figure 3: Land Use L and Cover (LULU) Supervised classification based on forest cover..

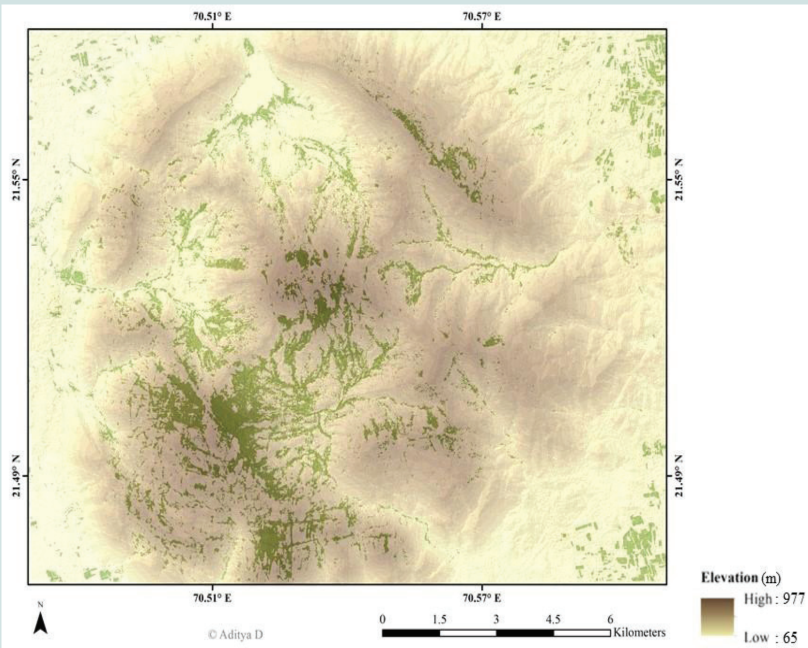

Figure 4: The areas covered by dense vegetation in the south western part of the sanctuary, which is situated at higher eleveation with sloppy terrain.

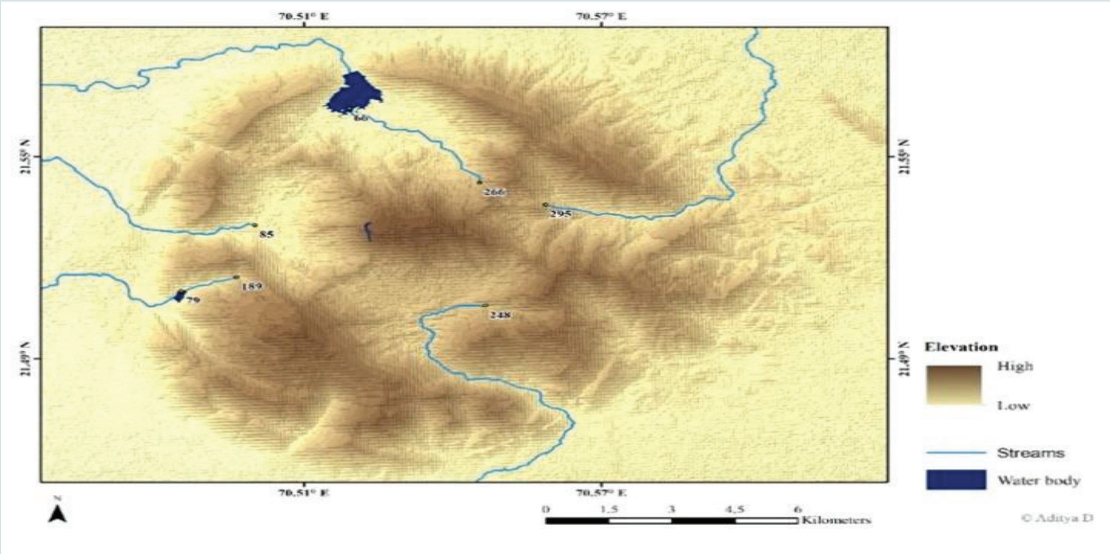

Figure 5: The pattern of water channels with respect to elevation in the sanctuary.

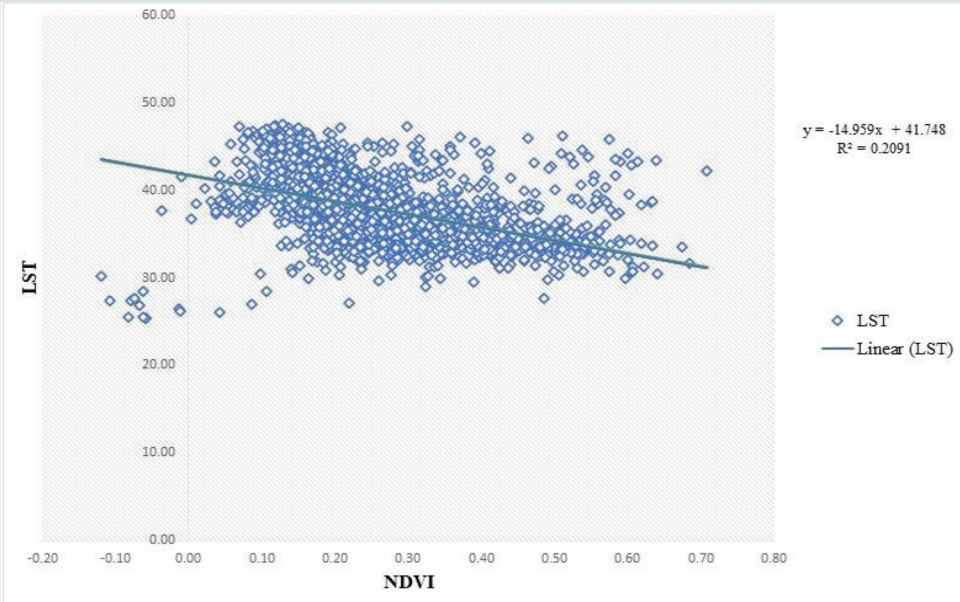

Figure 6: LST-NDVI inverse relationship from Landsat 8 OLI data.

first order streams, there is very less chance of getting calculating water catchment areas and the amount of water carried by each stream. Unlike the Girnar wildlife sanctuary, the other sanctuaries of Gujarat, like Jessore [48] and Ratanmahal, several junctions of streams were identified on the basis of STRAHLER order that provides an opportunity to wildlife manager to create the natural water catchment areas or check dams. The study reveals that, artificial water points such as wildlife guzzlers, artificial ponds, etc. need to be prepared in the barren areas of the sanctuary such as the Northeast and Eastern part as well as the origin points of all the five streams as depicted in Figure 5. These can aid in soil and moisture conservation as well as act as sources of water for the wild animals.

Land Surface Temperature

A habitat quality is often driven by the land surface temperature and (LST) influenced by the extent of vegetation and surface roughness. LST also helps in depriving various soil characteristics. Both NDVI and LST can act as indicators of drought as well [49]. In this study, the relationship between LST and NDVI is shown in the form of scatter plot using Landsat 8 datasets (Figure 6). The LST in the sanctuary has been ranged from 20˚C to 90˚C and the scatter plot depicts a negative or inverse relationship between LST and NDVI. With increasing NDVI, say denser vegetation, the LST gradually decreases which indicates that dense vegetation in the southwest of the Girnar sanctuary induces more evapotranspiration and cools the surface [50,51]. This plot also suggests that decrease in LST with increase in NDVI should not be interpreted as a sign of vegetation stress and hence LST could be a great determining factor to help in improving and understanding the water availability, to aid resource management and improve weather forecasts [52-54].

Conclusion

Remote sensing and geospatial analysis techniques may prove as effective and advanced tools to conserve the natural resources such as forests and water. In the present study, the forest habitat of Girnar hills and the water channel along with the Land Surface Temperature therein were analysed and mapped to understand the habitat availability for the Asiatic lion and its prey species. The outcomes thus, can be utilized for further assessment, evaluation and monitoring of this habitat for the conservation of Asiatic lion and its associated fauna. Alongside, the inverse relationship of LST-NDVI will might come handy in determining future environmental planning to maintain the vegetation density in the sanctuary. The water channels assessed might help the forest department to manage the water resources during the dry season through water conservation structures. The ability of GIS to capture, store and manage every type of datasets has proved that the outcomes deprived are self-understandable and self-explanatory to the laymen and persons who are unfamiliar with these emerging techniques. At a long term, the advancement in habitat management using geo-spatial technology will help forest managers, to formulate future conservation and management strategies.

Declaration of Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We sincerely acknowledge Dr. C.P. Singh, Scientist, Space Application ISRO, Ahmedabad Dr. Alpana Shukla, HOD, Botany Department, M.G. Science Institute, Ahmedabad, for critical review and encouragement. We also thank WCB Research Foundation and M.G. Science Institute, Ahmedabad, for the necessary facilities and the software.

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