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Read about Instinct behavior of captive Jungle Cat

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EDITORIAL NOTE

सा नो भूतस्य भव्यस्य पत्न्युरुं लोकं पृथिवी नः कृणोतु ॥१॥

– भूमि सूक्त, अथर्ववेद १२.१

She the mother earth who is the consort of the past and future (being a witness), may she expand our inner life in this world, through her vastness and purity towards the cosmic life.

Greetings to all our readers and contributors of 'Prithivya' on this important day of World Earth Day, celebrated annually on 22nd April, world over. The major environmental issues faced by the world that include Climate Change, Increasing Pollution levels, Environmental degradation, Resource depletions and many more, cannot be tackled at an individual's level or even by a single nation working alone. The united action by all the nations together would strengthen the conservation movements working for sustainable development, protection of ecologically sensitive areas and endangered species across the globe. The UN environmental program in it's 'Making Peace With Nature' Report in 2021, recommended adhering to the Sustainable Development Goals and working within the planetary boundaries to find amicable solutions to the abovementioned environmental issues. India, being one of the major Biodiversity hubs of the South Asian peninsula, is making consistent efforts in Biodiversity Conservation, especially in the 'In-Situ' conservation practices. India has 13 Biosphere Reserves, 485 Wildlife Sanctuaries and 87 National Parks, under the Protected Area network. A good example is that of an increased number of Tiger reserves from 9 in 1973 to the present day 27. One must understand the importance of nurturing such wildlife habitat that also supports a variety of flora and fauna of that habitat, adding to the intrinsic ecological and economical value of these practices. This in-turn benefits the overall development of socio-economic structure of the geographical area. However, this is not possible without the participatory role of the locals and conserving traditional knowledge and practices of the mother earth from each of these geo-ecologically diverse hotspots.

Today's youth shows a promise of being awakened and wanting to join the movements of nature conservation but it needs to choose the right platform with a readiness to work extensively on and off field. We, at WCB Research Foundation, are witnessing a change in the perception and willingness of the student volunteers to learn outside the four walls and get closer to the ground reality in the field of nature conservation. This would surely make them worthy to face the environmental challenges in the coming decades. It's our earnest appeal to our readers to explore such opportunities that would serve our mother earth and share these experiences with our future readers through articles published in journals such as 'Prithivya'. Let us all connect with Nature and recite the Earth Anthem by Abhay Kumar, who published it in 2009.

A New Millennium beckons us at its dawn and we must listen to its clarion call
All for one and one for all, United we sail, united we unfurl the blue marble flag!

Dr. Sagarika Damle
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DIRECTOR'S COLUMN

It gives me a great pleasure and a proud to present the second volume of "Prithivya", an official newsletter of WCB Research Foundation and I am delighted to share that our "Prithivya" is now recognized by National Science Library with the ISSN. This reflect the hard work of our dedicated editorial team and the support from our contributors as well as readers. Through "Prithivya", we are committed to provide the platform to researchers and wildlife aspirants and disseminate the science of conservation in the society through scientific and semi-scientific articles. Each article published in this newsletter are thoroughly reviewed and carefully checked for the plagiarism of less than 20% to not to compromise with the quality.

We are also making a progress in helping the young researchers through the initiatives such as WCBinar, capacity building programs and providing internship opportunity under the mentorship of our distinguished members from the various fields of conservation science and technology. Our sloth bear conservation project has successfully completed one year with significant outcomes well appreciated by our stakeholders. I take the opportunity to say a word of thanks to the Chief Conservator of Forests, Wildlife circle and Vadodara circle for their support and encouragement. Please read the annual progress report of our project "Aatmavat Sarvabhuteshu" on our website.

Under the coalition for wildlife corridor programme, we are developing the wildlife corridor profiles in collaboration with other fourteen conservation organizations, please visit the programme website to learn more. This year, we are also planning a National Conference on Wildlife and Conservation Biology, in which we will be inviting the eminent field researchers specially to interact with budding researchers. During the conference, the nominees of M I Patel Award will present their work. The nominations and applications for the M I Patel Award is open till June 30, 2022; I invite you all to come forward and nominate the young conservation researcher for this prestigious national award. We are also working to conduct a National Training Program and a field based workshop on conservation biology in near future. For all such exciting updates from WCB, please follow our social media: Twittter, Instagram and Facebook and subscribe our official YouTube channel.

I sincerely hope you will enjoy reading this first volume of the second issue of "Prithivya" and wish to have contribution of your scholarly research articles in the next issue. Please feel free to write us your feedback, suggestions and ideas for conservation initiatives and I assure you to implement them all in future. Lastly, let us observe the world Earth Day 2022 and help the organizations and individuals working to save the nature and natural resources.

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Plastic peril: Evidence of choked gut of Sambar (*Rusa unicolor*) due to intake of plastic in Ranthambore National Park, Rajasthan, India

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Plastic is one of the best inventions of humankind but unrestrained use puts it under the category of great threats to nature and humans themselves. Plastic has multiple uses and with cheap production cost, it captures the major packaging sectors which require covering or wrapping their product in cheap durable material. The real problem starts when single-use plastic comes into play with a lack of proper disposing guidelines, policies and infrastructures worldwide (Derraik, 2002). Plastic will remain as such for ages and will poison nature as no biological entity is able to break it down into simple compounds (Ganguly 2018). Before anyone knows and understands it starts affecting nature in hazardous ways. Every year millions of birds, fishes and marine animals became the primary target and got killed so terrestrial animals too got caught in this plastic wave (Susanti et al. 2020). Over half of the world's Sea Turtles are found with plastic waste in their stomachs. Cows can be seen consuming the plastic from urban dumpsters but the same is happening with wild herbivore species which inhabit the human-dominated rural landscapes near the wildlife sanctuaries and national parks. The Indian boar (*Sus scrofa cristatus*), nilgai (*Boselaphus tragocamelus*), chinkara (*Gazella bennettii*) (Menon 2014) and other herbivore animals are facing great dangers due to unmanaged plastic wastes which are dumped nearby fellow lands and forest areas. The single-use polythene bags are entangled with each other in the stomach of the animal and capture the stomach cavity which reduces the digestive space for the animal (Wabnitz & Nichols 2010). Plastic can cause choking of the digestive tract of animals

Figure 1. Chinkara (Gazella bennettii) in dried bush of Prosopis juliflora at Ranthambore National park boundary (05/07/2018) ***© Soufil Malek***

(Bjorndal 1994). Additionally, polythene also releases toxic chemicals which weaken animal health (Hammer 2012). I also witness the same misshape with animals during my field days.

I was lucky enough to get a chance to work in the famous tiger territory of Ranthambore National park, Rajasthan during the tiger cycle 2017-19. Ranthambore national park with an area of 329.50 km^2 is home to 239 Vertebrate species, from which 31 are Mammalian species (ZSI 2010). As a research biologist of "All India tiger estimation exercise", we got good accessibility to tourist and non-tourist areas of the national park to complete the research work. It was the fifth day of a fiery afternoon of the month of June, 2018; we were roaming at the boundary areas of the national park to select the proper location to place our camera traps. This boundary of the park is full of invasive thorny shrub *Prosopis juliflora* or "Vilayati babul" (Dayal 2007), so we are unable to get proper shade and are irritated from the scorching heat of midsummer. Our driver Kalubhai drives slowly on forest paths and we suddenly smell a strong rotten smell which fires up the team. I and my fellow researcher Ravi instantly decide to locate this carcass in the hope to see a large carnivore as it may be on potential kill. We saw two carcasses, one is fresh and another one looks a little old, maybe a couple of days old from a safe distance through the dense bush. We wait for almost ten to twenty minutes before reaching near to it to collect samples.

Figure 2. Photographs of dead Sambar (Rusa unicolor) with plastic material (05/07/2018) ***© Soufil Malek***

Our excitement instantly replaced with despondent when we reached the scene of this "potential kill site". The murder of crows was feasting on two carcasses of the "Sambar deer" (*Rusa unicolor*) (Menon 2014). We caught ourselves in shock and fell in agony for the animal. The half-eaten half-rotten animal gut was full of single-use plastic bags. It took the shape of a stomach. The other dead animal does not have any hunting marks on it so we are sure that it was not a kill of any carnivore species. When we visit that location again after a

week we find the same type of plastic inside animal gut as it was eaten by other small carnivores and crows. The area was at the boundary of the national park and a village. We came to know that they use forest boundaries as a dumping site and as these animals generally roam around the village primacies' and consume the plastics with garbage. The single-use plastic is proved as a menace again and again for domestic and wild animals as well. As a human, we all are held responsible for not working in the direction of reducing such incidence. A balanced combination of social awareness to villagers and proper policy implementation is the key to protecting our animals from eating and dying unnatural death.

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Diversity of Mantis (Insecta: Mantodea) in Sundarvan-A Nature Discovery Centre, Ahmedabad, Gujarat, India

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Abstract:

The present study was conducted during the year 2021 with the objective to explore the diversity of the Mantis sp. at "Sundarvan-A Nature Discovery Centre, Ahmedabad (Gujarat, India)".Present study documents the observation of different species of Mantis at the Study field; data was collected by handpicked method. From the data it is concluded that mainly 5 known species belonging to 5 genera and 4 families were found in the study field. All 5 species, Creobroter apicalis (Westwood, 1889), Humbertiella ceylonica (Saussure, 1869), Detroplaty slobata(Guerin, 1838), Miomantis paykullii (Stal, 1871), Odontomantis planiceps (Giglio, 1913) were found in the study field during the observation period.

Key Words: Species diversity,Mantids,Conservation,Insects

Introduction:

Insecta is the largest class of animal kingdom under the phylum Arthropoda. Insects can be described as primarily with six legs or appendages and usually a chitinous exoskeleton. Mantidae family is the largest family in Mantodae order of the class Insecta. Mantids are distributed worldwide in temperate and tropical habitats. Mantis falls under the Class: Insecta, Order: Mantodae, commonly known as Praying Mantis. There is significant place of mantids in the ecosystem as predators. These animals mainly feed on grasshoppers, moths, butterflies and flies, aphids and also they are well adapted in camouflage and mimicry (Sureshan PM, Sambath S., 2009). The commonly identified mantids are called "praying mantis", it is because of unusual way of raising their two fore legs in a posture of prayer. These species can be found waiting tranquil for hours together for their prey and can rotate their head up to 180degree (Sureshan PM, Sambath S., 2009).

Mantids are diurnal and are attracted to lights at night (Dutta, W & Sur, D. 2012). These are weak flies and can be found sitting on herbs, shrubs and trees (Sathe, T. V. & Vaishali, P. J. 2014). There are around 2300 species of mantids under 434 genera all over the world (Patel, H. N., Shukla, A. & Prajapati, J. N. 2018). According to a study by Mukherjee *et al* (1995), in India there are moderately diverse fauna of mantis with 162 species under 68 genera of 6 families. In the recent years there is increased attention towards the taxonomic studies of the mantis fauna of India, due to which the description of some interesting new taxa from the country is also come up (Ghate and Ranade, 2002; Ghate and Mukherjee, 2004; Thulsi Rao *et*

al., 2005; Sureshan*et al.*, 2004 a, b, 2006 a, b, c; Vyjayandi & Narendran, 2003, 2005; Vyjayandi*et al.* 2006, Vyjayandi, 2007). The objective of this study is to contribute to the knowledge of biodiversity of praying mantis in Sundarvan Park.

Study area:

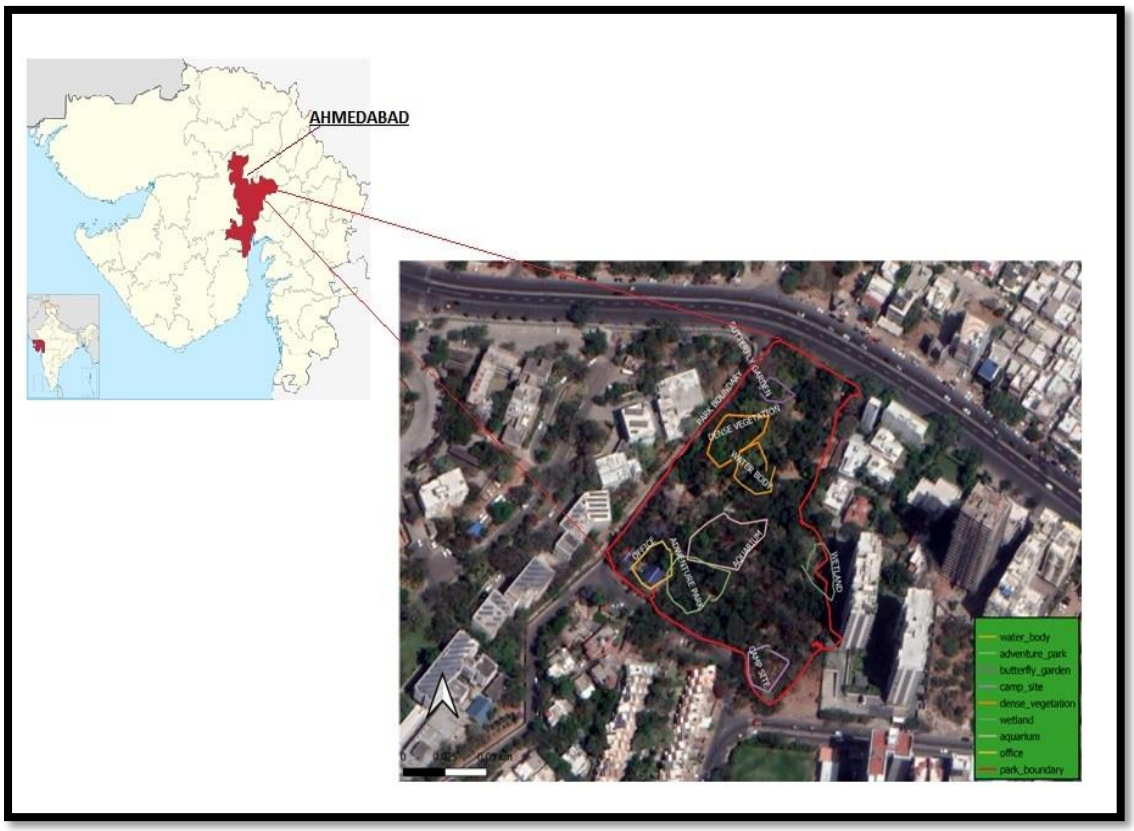

Figure 1. Study Area (Enlarged- Sundarvan- A Nature Discovery Centre, Ahmedabad)

The study was conducted at the **Sundarvan-A Nature Discovery Centre** set in the heart of Ahmedabad city, Gujarat, India. It is a mini zoo with dense vegetation in its premises, however it lies in the hustle of the busy city, Sundarvan is indeed an escape to the nature and peace. Different species of large trees, lush green area and mini cages with small birds and animals it is truly a blissful place to enjoy the moment of peace though it is open for visitors it still has a lot of space that remain undisturbed and where the wild diversity can be observed in its natural habitat including some reptiles, birds and insects. It is a unique facility of the Centre for Environment Education (CEE), Ahmedabad. This four-acre land was originally a mango orchard, converted into a nature discovery center on October 28, 1978. It is a green oasis of the city and has been categorized as a mini zoo, by the Central Zoo Authority (CZA), the apex governance body for Zoos of India.

Methodology:

The data collection was done in the year 2021 for few months, using handpicking method. Observations were followed by collection and photography from the areas of the study field where the observations were carried out. For their identification purpose photographs were taken with the help of mobile phone camera and Nikon D5200-18-140mm lens, for tracking precise location of each species the GPS device Garmin (Garmin e-trex 10) was used. For identification, the mantis specimens were sacrificed in killing jar and spread and pinned. The initial identification, of the praying mantis was done with the help of the standard book- "A*n introduction to rearing praying mantis"* by Phil E. Bragg. 1997.

Results:

The observed Mantids in the study field are of order Mantodae is represented by 5 species belonging to 5 genera of 4 families. Species observed in the study area are illustrated in table 1 and described in table 2.

During the study, the distribution of the species was observed along with their GPS location (Figure 2). Table below, briefly explains the distribution of the Mantids species at the Sundarvan-A Nature Discovery Centre

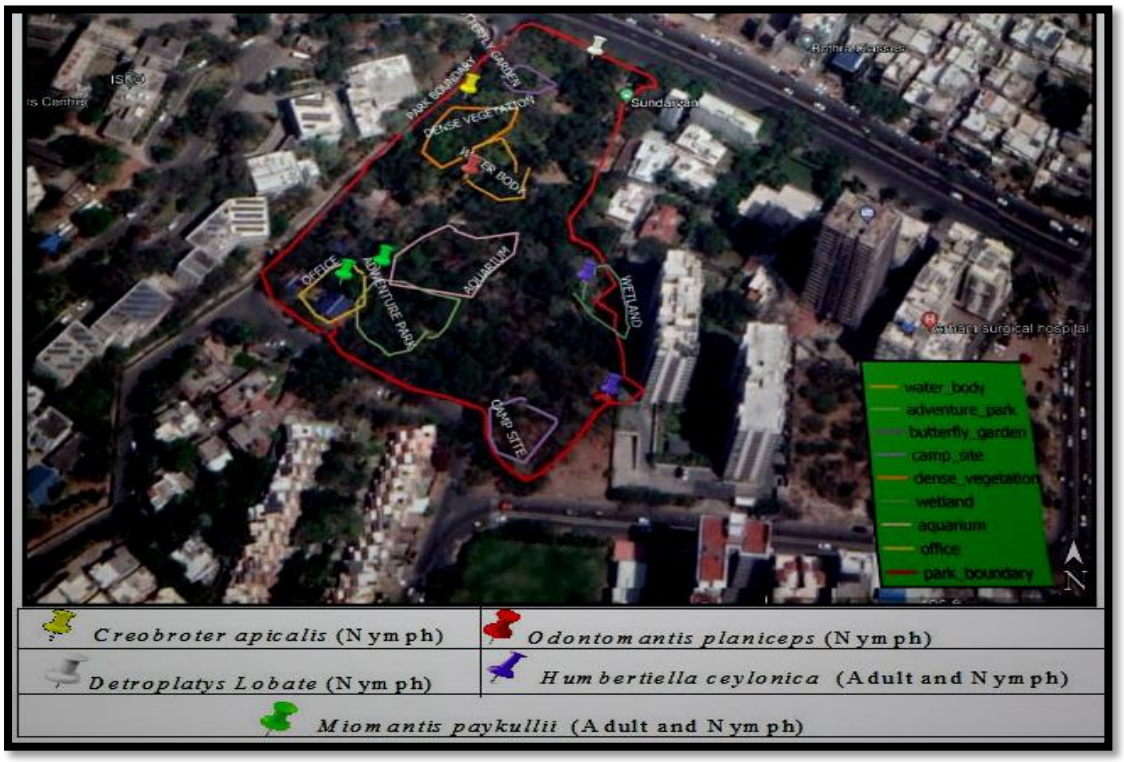

Figure 2. Sundarvan Park map locating GPS position of the observed mantids species in the study field (Source: Google Earth)

Table 1: Species of Mantids observed inthe Study field

Family: Hymenopodidae

Species 1: ***Creobroter apicalis***

Species 2*: Odontomantis planniceps*

Family: Gonypetinae

Speceis 3. ***Humbertiella ceylonica (Adult and Nymph)***

Family: Detroplatyidae

Species 4: ***Detroplaty slobate (Nypmh)***

Family: Miomantidae

Species 5: ***Miomantis paykullii*** **(Adult and Nymph)**

Table 2: Distribution of Mantid species with their GPS location and associated flora

No.	Mantis Species	Common Name	Life Stage	Found on (flora/ place)	Location (Co-ordinate)
1	*Creobroter apicalis* (Westwood,1889)	Indian Flower Mantis	Nymph	*Hibiscus rosasinensis* (Hibiscus plant)	N: 23°01'36.37" E: 072°31'15.58"
2	*Humbertiella ceylonica* (Saussure, 1869)	Bark Mantis	Nymph	*Leucaena leucocephala* (Subabul tree)	N: 23°01'33.15" E: 072°31'17.36"
			Adult	*Bartariacristata* (Philippine violet)	N: 23°01'34.81" E: 072°31'17.11"
3	*Detroplaty slobate* (Guerin, 1838)	Dead-Leaf Mantis	Nymph	Ground	N: 23°01'38.38" E: 072°31'17.36"
4	*Miomantis paykullii* (Stal, 1871)	Praying Mantis	Adult	*Pandanus odorifer* (kewda)	N: 23°01'34.81" E: 072°31'13.92"
			Nymph	*Thevetia peruviana* (pili Karen)	N: 23°01'35.01" E: 072°31'14.42"
5	*Odontomantis planiceps* (Giglio, 1913)	Ant-Mimic Mantis	Nymph	*Hibiscus rosesinensis* (Hibiscus plant)	N: 23°01'36.37" E: 072° 31'15.58"

Discussion:

Existence of diverse species in the confined area of the vegetation surrounded by the city explains the richness of flora and fauna of the study area. It also indicates the quality of habitat of the Sundarvan for different fauna species as each are interrelated to other. To explain the distribution of each species the location coordinates were noted.

Each species was found in the widespread area of the study field. These all 5 species are found on the plants like *variegated hibiscus*, *Hibiscus rosasinensis*, *Pandanus odorifer*, *Leucaena leucocephala*, *Barlaria cristata*and, *Thevetia peruviana*. Abundance of such species in the middle of a big and busy city indicates environment of the place and it encourages one to conserve the habitat for the diverse fauna and flora.

Acknowledgements:

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Stimulation of instinct behaviour in captive Jungle Cat (*Felis Chaus*) with feeding and sensory enrichments at Rajkot Zoological Park-Rajkot

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Abstract:

Behavioural observations and various enrichment tools help to stimulate instinct behaviours in wild captive animals and provide better physical and mental health for the animals. The present study was conducted from October 2018 to February 2019, at Rajkot Zoological Park, Rajkot, Gujarat. Two male Jungle cats (Felis chaus) were observed in captivity through direct observations. The observations were made thrice in a week from 9:00 am to 12pm. The frequency of behavioural activities was recorded and calculated by Altman focal sampling method. Two types of enrichments were provided (feeding and sensory) randomly to avoid habituation. Results of the data analysis of pre and post enrichment experiments show that enrichment can reduce stereotypic and inactive behaviours in both the cats, and increased the active behaviours. In this paper, we report the recent sightings of the Sociable.

Key Words: Small cat, Enrichment, Captive felids, Stereotypic behaviour

Introduction:

Zoo community was among the first to raise concerns over abnormal and stereotypic behaviors in captive animal and to begin to develop environmental enrichment strategies to deal with the perceived problem. Stereotypes are relatively in variant, repetitive behaviors that seem to have no immediate function (Mason, 1991). In the zoo community, environmental enrichment has become almost a catchall term for husbandry activities with the specific aim of improving wellbeing and as such is the method of choice for reducing stereotypic behavior. Environmental enrichment involves changing the environment of the captive animal to provide opportunities or choices not available before. Often a heavy emphasis is placed on the importance of providing enrichment that is appropriate to the specific biology (to the extent to which it is known) of the species under consideration (Mellen and MacPhee, 2001).

Biologically appropriate complexity can be increased in many ways, by adding substrates that increase the information content of the environment and elicit foraging and investigatory behavior by concealing food, smells, naturally occurring insects, other wildlife, etc. Barriers and landscaping can provide privacy, promote territorial behavior, provide escape routes, and thus improve social interactions. Climbing structures allow more efficient use of space and provide shade and temperature gradients for the choice of microclimate. They can also

provide hiding places from conspecifics, the public, and keepers. More recently, the potential of training, not just as a management tool but also as cognitive enrichment for captive animals, has begun to be realized (Laule and Desmond, 1998).

The Jungle cat (*F. chaus*) is considered one of the widely distributed yet least studied species in India. It is also known as a reed cat or swamp cat. It occurs in North Africa and is widespread in Asia from the Middle East, Southwest Asia, Central and South Asia over to Southeast Asia, reaching Indo-China and possibly the Malayan Peninsula (Abu-Bakeretal.2003, Duckworthetal.2005, Sanei et al., 2016). Ten subspecies of the Jungle cat have been proposed so far based on the diversity of morphological traits (Heptner & Sludskii 1972), but no genetic or cranial analysis was carried out yet to test this hypothesis (Duckworth et al.2008).

The purpose of the present study is to observe and analyze the health of Jungle Cat in captive condition; opting behavioral activities and enrichment as a management tool at Rajkot Zoological Park, Rajkot, Gujarat. The study aimed to understand the positive effects on the behavior of jungle cat after providing enrichments.

Methodology:

Study site:

The study was conducted at Rajkot Zoological Park, Rajkot Gujarat (22°174 N and 70°503 E). The zoo is located in between two lakes named Randarda lake and Lalpari lake with hilly and rocky terrain. Its geographical location is (Fig1).

Figure 1. A Google Earth® image showing the geographic location of Rajkot Zoological Park

The Display exhibit is a large landscape and allow for public viewing of the animals. Two cats were kept in the enclosure inside the night shelter at night or when not available for public viewing.

Environmental enrichments of exhibit enclosures for jungle cats were provided for behavioral and physical improvement; which enhancing zoo animal environment to perform several activities and care within the context of their inhabitant of exhibit closures. The environmental enrichments, such as vegetation layers small tree, large tree for climbing, clawing and watching, table top for resting and sitting, concrete steps for climbing concrete shelf for play, jump, watch, swinging tool for play, the roof for shed and cover that provide for a walk, hide and watch. (Figure 2)

Figure 2. Enclosure with environmental enrichment tools of Jungle cat at Rajkot Zoological Park (Inside View) ©Rupal Pala

Observations and Data analysis:

The experiments were carried out from October 2018 to February 2019 during the winter season for master's dissertation. Continues observations on two individual jungle cats were made in a day time 09:00hr to 12pm thrice in a week. A total of 94 hours of data were collected including pre and post enrichment experiments. Two individual animals, Cat1 (male, 4 years old), Cat2 (male, 5 years old), were selected and observed for data collection.

The frequency of the behavioral activities was calculated by Altman focal sampling method. (Altman 1974). For data analysis, prime behavioral activities were considered.

Feeding and sensory enrichment experiments were conducted for 3 days set by morning hours, randomly to avoid habituation. Regular feeding time was in the evening by 6:00pm. Animals were fed six days a week with a day fasting on every Friday. Post enrichment experiments were done randomly for 8 days and data of 25 hours was collected.

Experiment 1: Sensory enrichment

Fresh fish was rubbed at various places in-display exhibits such as a tree, small wooden pole and hanging ball to stimulate the feeding sensation.

Experiment 2: Feeding enrichment

Fresh fish and boiled eggs were hidden at several places in-display exhibit to encourage seeking and foraging purposes.

Statistical analysis was carried out by calculating the standard deviation, of a total mean of important behavioral activities of both the cats. Such as resting, licking, pacing, climbing, spray marking, defecating, standing, drinking, scratching, sniffing, sitting, aggression and fight.

Results:

We categorized the behavior activities of both the jungle cats, which were most frequently displayed, such as resting, sleeping, licking, walking, climbing, urination, defecation, standing, drinking, scratching, smelling, sitting, aggression and fight.

The analysis of data shows that both the cats were displaying stereotypic behavior in pacing (Cat1 63.7%, Cat2 67%) and resting (Cat1 33.27%, Cat2 66.94%) among all the other activities (Figure 4 and 5) before the enrichment experiments. After providing feeding and sensory enrichments improvements were observed in instinct and active behavior such as sniffing 7.94%, climbing 7.15%, was observed and the pacing was significantly decreased from 63.57% to 4.72% and resting was decreased from 33.27% to 2.61% in Cat-1. Similarly, Cat-2 also improvement in instinct and active behavior was reported such as sniffing 26% climbing 23%, and resting was decreased from 66.94% to 9% and the pacing was decreased from 67.70% to 16%.

Figure3: A jungle cat displaying stereotypic activities before the enrichment experiments such as Pacing and Resting Fig: 3 a, b, and improvement was seen in other activities after providing feeding and sensory enrichments such as sniffing and climbing. Fig: 3 c, d, © Rupal Pala

During the study period through direct observations, it was noticed that sensory enrichment (fish rubbing at a random place of the enclosure) helped in the enhancement of sniffing and foraging while feeding (boiled egg, fish) helped in climbing and territory marking enhancement.

Discussion:

Response to the enrichment experiments was seen in both the individuals, after providing the feeding and sensory enrichments. In zoos, stereotypic behaviour such as pacing and inactive behaviour such as resting are common due to the captive environment (Mason, 1991) though the captive environment provides natural surroundings. Due to solitary habits with large territories, they become stereotypic in captivity.

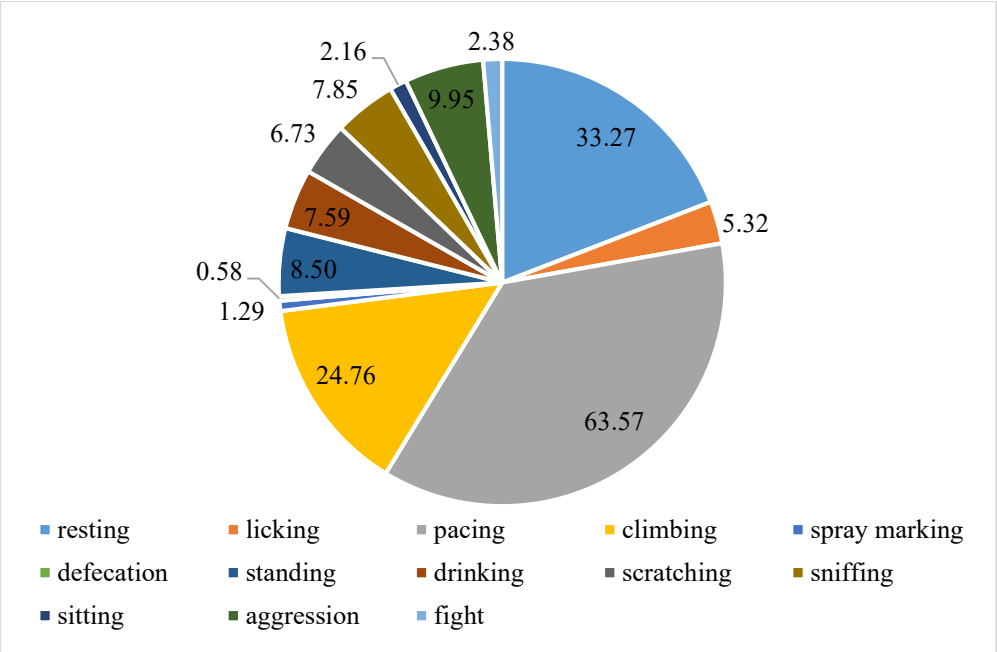

Figure 4(a): Standard deviation in % of the frequency of behavioral activities of Cat-1before enrichment (total 69 hours)

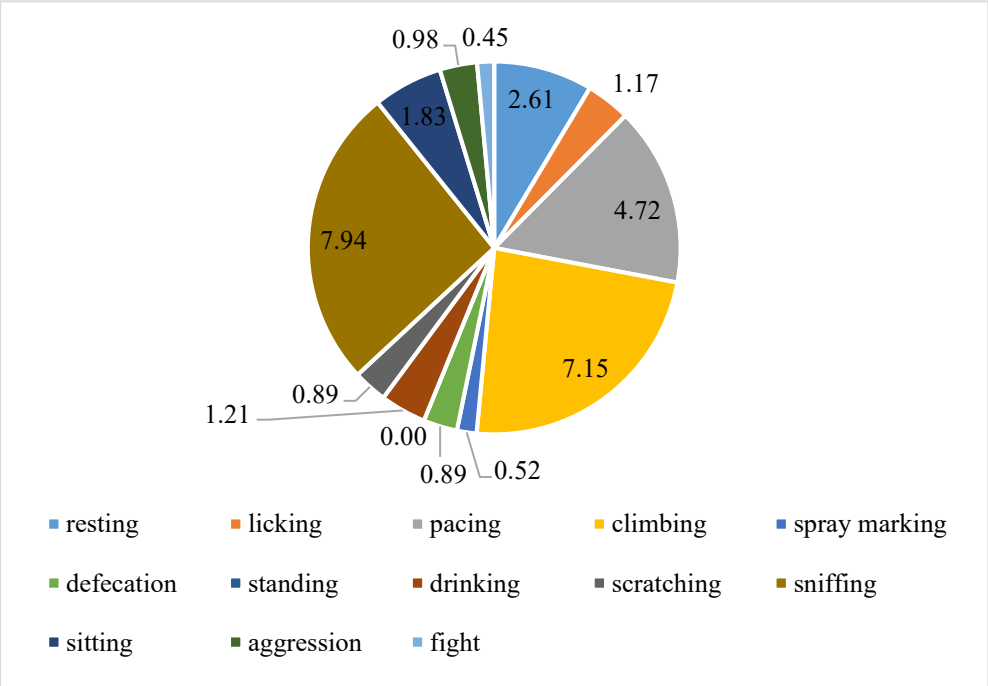

Figure 4(b): Standard deviation of the frequency of behavioral activities of Cat-1 after feeding and sensory enrichment (total25 hours.)

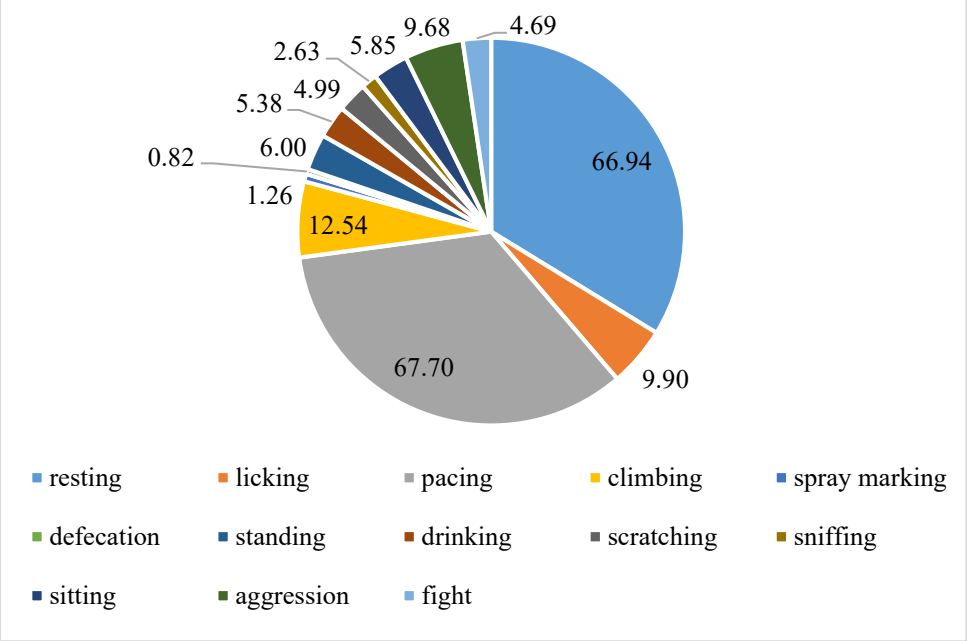

Figure 5(a): Standard deviation (%) of the frequency of behavioral activities of Cat-2 before enrichment (total 69 hours)

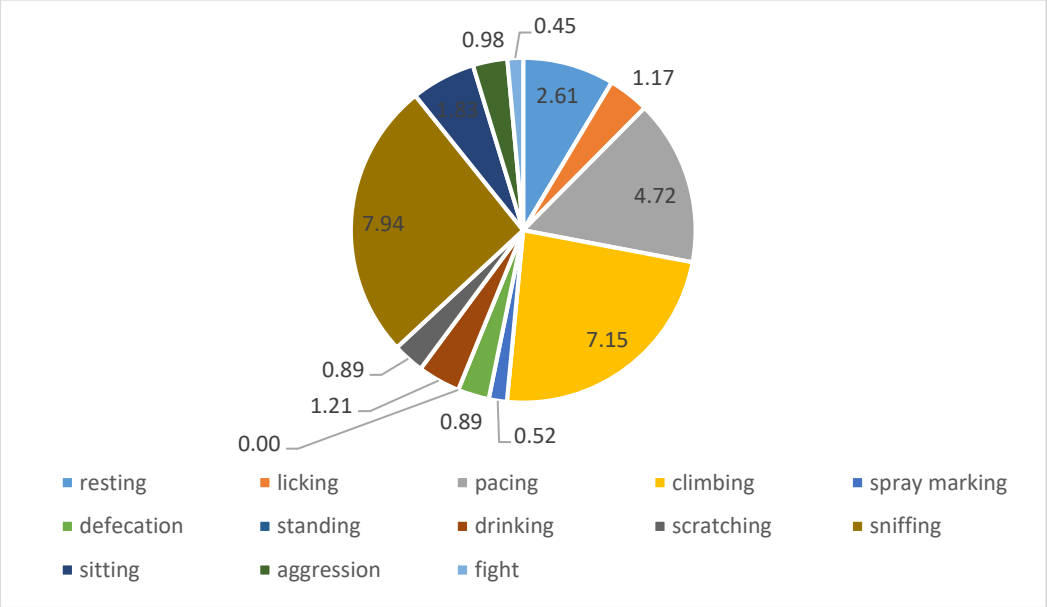

Figure 5(b): Standard deviation (%) of the frequency of behavior activities of Cat-2 after feeding and sensory enrichment (total25 hours)

Sensory enrichment can improve their natural behaviours such as foraging and sniffing while feeding enrichment can enhance their other natural behaviours like climbing, maintenance and may reduce over aggressive and stereotypic behaviour (Shepherdson et al.1993).

However, response to the enrichment tools may vary according to the condition of health and age of the individual (Debora et. al, 2018).

In present study we observed that Cat2 was dominating on Cat1 in its territory, such as on a roof, on the bench and step at the right corner of the enclosure. Which covers approximately 70% area of the enclosure. Territory marking was done by spray marking or clawing most of the time.

The study also supports the previous studies by Mellen and MacPhee, (2001) and Laule and Desmond (1998) that effecting stimulation of instinct behaviour after providing the feeding and sensory enrichments. Benefits of environmental enrichments were seen in both the cats, by increased active behaviours. However, changes in behaviours were varied in both the individuals.

Conclusion:

Results of the present study show that the physical and mental health of the animals can be improved through enrichment by encouraging their instinctive behaviors. The health of the animals is disproportionately important to pass the better traits to their offspring. It is also one type of holistic approach that one can do to keep the captive animals stress free, and mentally as well as physically healthy.

Acknowledgements:

We are grateful to the authorities, Dr R K Hirpara, Zoo Superintendent, Rajkot Zoological Park for permission to conduct this study and encouragement. Thanks to the entire staff of the zoo, colleagues and family members for direct or indirect help and for providing all the facilities to complete this work.

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Linking biodiversity to economy- a much needed step towards conservation

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According to the United Nations Food and Agriculture Organization, biological resources account for 40% of the global economy (Gitz et al.2016). Biodiversity is the variability of different life forms in genetic, species or at ecosystem levels (Silvert 2006) and is important for providing a smooth and stable functioning of all macro and micro level processes at different scales throughout the earth (Ibisch et al.2010). From this, if any one component is disturbed or removed it impacts the whole ecosystem and its other components. It is like a chain process wherein each component has an interconnection with another component giving rise to a complex web. Not only there is an impact upon the food chain but also on the species behaviour, ecology, and different patterns and processes (He et al. 2013). Maintaining biodiversity is crucial for the various ecosystem services viz., organic waste disposal, soil formation, biological nitrogen fixation, crop and livestock genetics, biological pest control, plant pollination, pharmaceuticals, food industry dependent on pollinators like Bees, and also for preventing the spreading of diseases (Pimentel et al. 1997).

India being a developing country with a rich biodiversity and where millions of people among the struggling communities directly or indirectly depend on nature and its resources for their day-to-day livelihoods (Khoshoo & T. N. 1994). Ecosystems with high biodiversity are a major potent in food, fuel, medications, and other things. People utilise these natural resources for their own benefit as well as a source of revenue (Shaw 2018). The poor rely significantly on biodiversity for subsistence, and in some cases, biodiversity protection can be a means of escaping poverty (Billé et al. 2012); the activity of a diversified natural biota is required for both excellent agricultural output and human health. Biodiversity remains poorly measured and demonstrated, with many changes occurring subtly on timescales that are not immediately evident to the vast majority; biodiversity conservation and poverty reduction are two global challenges that are linked (Billé et al. 2012)

The Millennium Ecosystem Assessment in 2005 was the first global initiative to investigate the linkages between human well-being and biodiversity (Gaglio 2018). This assessment

discovered that biodiversity improves societies in material welfare, community security, local economy resilience, intergroup relations in communities, and human health. It also highlighted the phrase "ecosystem services" in four major areas (Morton & Hill 2014) - provisioning services, controlling services, ancillary services, Cultural services, such as spiritual and recreational advantages.

Biodiversity is crucial, particularly the development of natural areas, are generating a species extinction rate 1,000 to 10,000 times the natural rate, which is critical for the sustainable functioning of the agricultural, forest, and natural ecosystems on which humans rely (Singh 2002). Extinction of any species results in the irrevocable loss of a portion of the Earth's biological richness (Barbier et al. 2019). Biodiversity as a means of subsistence and income to the poor can tend to solve many major challenges in the modern day developing countries (Menzel & Bögeholz 2009). Indian economy is made up of the service sector, agriculture sector and manufacturing sector distributed across the length and breadth of the country (Chakraborty & Nunnenkamp 2008). Biodiversity and natural resources constitutes the backbone of all sectors of the economy of our nation (Kim et al. 2006). This Dependency on the nature is an indirect threat risking the potential existence of the pristine untouched biodiversity thereby altering the environmental processes and opening major challenges towards wildlife conservation by exploiting the habitat and natural resources (Koziell2001). So, the question arises now that, how we can balance our dependency as well as exploitation. This is a major trouble for the present day conservationists.

Economic bureaucrats focus on the economic benefits and developments needed to efficiently sustain human lives globally, this in turn neglects the intricate value of biodiversity makes our dependency resorted towards exploitation (Prugh et al. 1999).The solution to this major challenge is communication, Communicating with the different sectors and their leaders and highlighting the importance of biodiversity in our day to day lives and human development (Deneulin & Shahani2009). Educating and making people aware can drive people towards thinking ways of eco-development, considering both the ecosystem and human development altogether, Awareness is the major key to any such situation wherein we need to protect the intricate natural resources that we are blessed with. Educating the local tribes, policy makers, Diplomats, laymen about the importance of biodiversity and their indirect economic benefits can solve this problem. People gain from healthy ecosystems in terms of economic and other benefits, and it is only then that their long-term survival becomes assured.

As stated in the World Summit on Sustainable Development Implementation Plan, sustainable use is also an effective instrument for combating poverty and, as a result, achieving sustainable development (Omer 2008). A significant shift in perception can aid in the restoration and protection of biodiversity (Buijs 2009). It entails restoring vegetation along watercourses and reintroducing natural links into the environment so that when species begin to move and respond to climate change, they have a place to go.

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Lotus fibre – A possible solution to textile pollution: A review

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Abstract:

The textile industry has been a significant pollution causing sector globally. Concerning environmental protection and sustainable development, the development and application of natural plant fibre and renewable fibre will be the inevitable trend in the future. One such fibre can be obtained from the Nelumbo nuciferastem, root, and peduncle. India has a wetland ecosystem that supports diverse and unique habitats, suitable for Lotus production. Lotus silk production in India is limited to Eastern states like Manipur, while in industrial states like Gujarat and Maharashtra, lotus fibre production is not seen on an impactful stage. Lotus fabric can be mass-produced and popularized in India through proper training of local people. It can prove to be a big employment generating industry and can also help to reduce the carbon footprint of the current textile industry.

Key Words: Nelumbo nucifera, Lotus fibre, natural fibre, Textile, Sustainable development

Introduction:

The textile industry is the second-largest pollutants releasing industry of the world (Sharan and Haldar, 2021), with pollution areas ranging from Water pollution (Kant, 2011), Microfibre pollution (Liu *et al.,* 2021), Metals pollution (Li *et al.,* 2021), Noise pollution (Zare Sakhvidi*et al.,* 2021), Air pollution (Meenaxi and Sudha, 2013), Waste generation (Desore and Narula, 2018).According to an estimate by World Bank, 17 to 20% of total industrial water pollution comes from waste produced after the dyeing and finishing treatment of various textile products (Kant, 2011). Fibre2Fashion's (2012) survey shows that nearly 5% of all landfill space is consumed by textile waste. The raw material to produce textiles, i.e., fibre, can be classified into three major categories: cellulose, protein, and synthetic fibre (Ghaly*et al.,* 2014). Fibres from plants such as cotton, flax, hemp, ramie, etc., are examples of cellulose fibres. Protein fibre is animal-derived fibres like wool, angora, cashmere, and silk. Synthetic fibre is synthesized from petroleum-based products such as polyester, nylon, spandex, acrylic, polypropyleneetc, (Pensupa*et al.,* 2017). Cellulose materials are the most economical and most abundant renewable resources in nature. With the depletion of non-renewable resources such as coal, oil and natural gas, it has been a serious problem for people to look for substitute renewable resources. In environmental protection and sustainable development, the development and application of natural and renewable fibre will be the inevitable trend (Zhao *et al.,* 2015). One such naturally fibre-yielding aquatic

plant is lotus (*N. nucifera* G) which is a perennial plant with rhizomes that grow in muds belonging to Nelumbonaceae family of Proteales order. It is a vital plant with its uses varying from ornamental, nutritional, and medicinal (Lin *et al.,* 2019). It is being proposed as a potential source of fibres for the textile industry (Patil, 2018; Tomar and Yadav, 2019).

Figure 1. Lotus growing in natural habitat

The wetland ecosystems in India supports diverse and unique habitats (Bassi *et al.,* 2014). The soil system in wetlands are known as hydric soil, suitable for growing lotus plants (figure1). Lotus is an important cash crop cultivated throughout the country for its wide range of uses. Lotus shows all the aquatic plant features like aerenchyma and the certain unique features that differentiate it from other plant species are also present, like seed longevity and leaf ultra-hydrophobicity and floral thermoregulation. A detailed understanding of the mechanisms responsible for forming these unique properties is important for the basic plant biology and their great potential usage in other areas like bionics, tissue engineering, and regeneration (Nie*et al.,* 2008). The fruit of *N. nucifera* is well-known for its longevity (Lin *et al.,* 2019). Lotus roots are planted in the soil of pond or river bottom, whereas the leaves float on the water and have a hydrophobic layer on the dorsal surface. The plant typically grows upto about 150cm and a horizontal span of about 3 meters. Leaves may be as large as 60cm in diameter, while the flowers can be upto 20cm in diameter when open (Sheikh, 2014).

Lotus is widely distributed in Southeast Asia and is a National flower of India. Other than India, it is also the National flower of Egypt and Vietnam. In India, Nelumbo is distributed from Kashmir to Kanyakumari, showing vast phenotypic variety in shapes, sizes and shades of flowers having petals between 16-160 (Sharma and Goel, 2000).

The fibre–producing lotus is distributed worldwide. In Gujarat state, it is cultivated in Ganeshpura, Savli Taluka**,** Kamlapura Village, Ruvad and Tarsalivillages of Vadodara district (Sharan and Haldar, 2021) (figure 2).

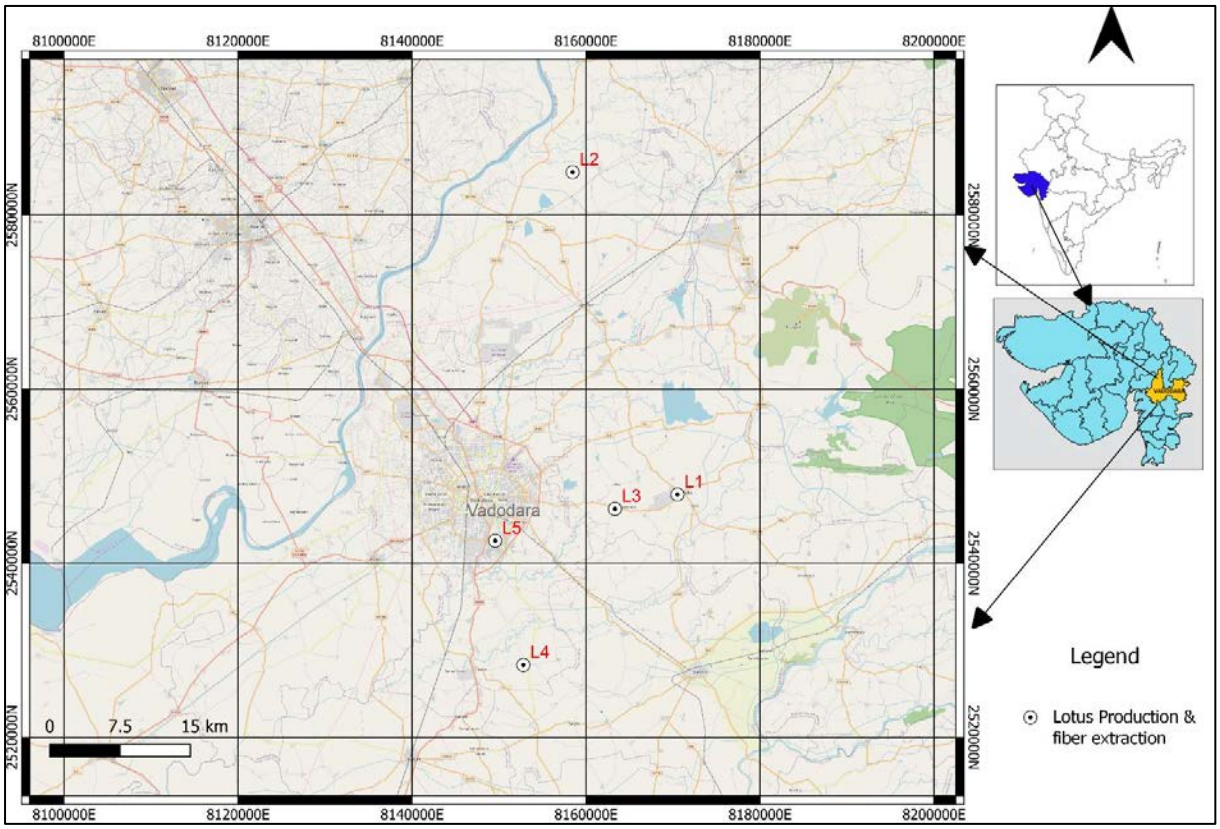

Figure 2. Lotus cultivation and fibre extraction around Vadodara district. L1: Ganeshpura Village, L2: Savli Taluka, L3: Kamlapura Village, L4: Ruvad village, L5: Tarsali village (Sharan and Haldar, 2021)

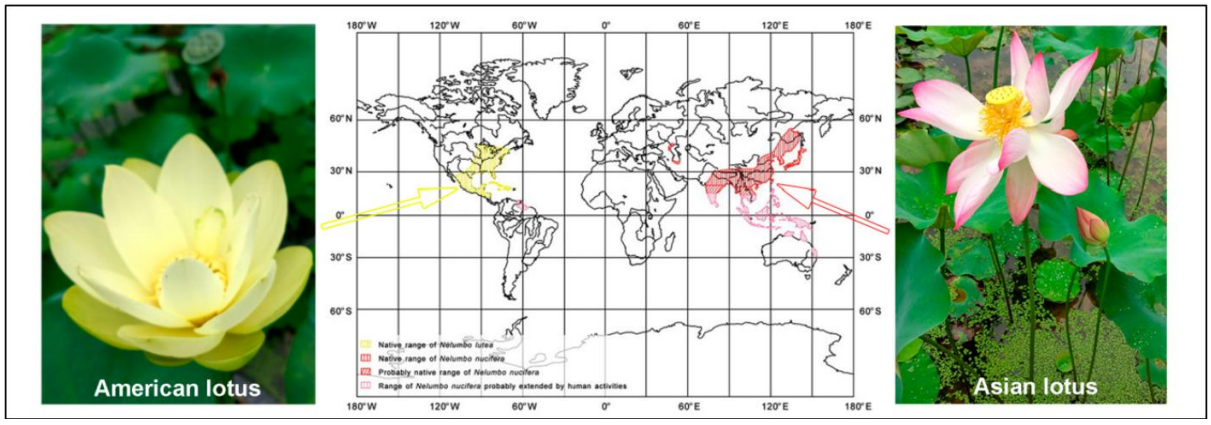

Figure 3. Global distribution of two Lotus species. The left and right panels show the flowers of American (N. lutea) and Asian lotus (N. nucifera), respectively (After Lin et al., 2019).

N. lutea Willd is mainly distributed in the North American sub-continent. Whereas *N. nucifera* Gaertn is distributed in the Southeast Asia as shown in Figure 3 (Lin *et al.,* 2019).

The plant also provides fibres used to make a rare kind of cloth matching with the prime qualities of silk (Gardetti and Muthu, 2015).

After harvesting, many lotus petioles are considered waste and dumped for natural decay. Such debris may cause environmental degradation (Chen *et al.,* 2015). This review focuses on lotus fibre which could be used from the waste of petioles; so the local cultivars could provide the waste when required to produce fibres.

Lotus fibre:

Lotus fibre develops in vascular bundles of leaf, stalk (Liu *et al.,* 2009) and root of *N. nucifera*. (Gan *et al.,* 2009). Botanically, the fibre is the thickened secondary wall in xylem tracheary elements (Pan *et al.,* 2011). Many new plant fibres are introduced to achieve an environment friendly future of the textile industry. One such promising option is extraction of fibre from lotus plant. Lotus fibre is a biodegradable fibre that can be extracted from roots (Nie*et al.,* 2008), stem (Patil, 2018) and peduncle (Pandey*et al.,* 2020) of the plant. Fibre from lotus stem, the most common source, is being extracted since 1910. The lotus fabric is the first natural microfiber i.e., its fineness ranging from 3.963-4.516µm (Zhao *et al.,* 2015) and perhaps the most eco-friendly fabric in the world (Patil, 2018). The fabrics made from lotus fibre are having great application and demand in the textile sector, especially in the luxury sector. The lotus fibre fabrics can be best described as in-between silk and linen; the lotus flower fabric is naturally stain-resistant, waterproof, and soft. This soft, breathable, wrinkle-free fabric was once used to make robes for senior Buddhist monks (Gardetti and Muthu, 2015). Gupta (2020) called lotus fibre as “Spiritual fibre” due to the inspiring way of growing the lotus plant in the mud.

Properties of lotus fibre:

A study was conducted by Wang *et al.,* (2008) to understand the fundamental physical properties of the lotus fibre, in which they stated that the density of lotus fibre varies between 1.184g/cm^3, much less than cotton, ramie and wool fibres, but similar to silk. The linear density of lotus fibre was 1.55 dtex (10,000m of lotus fibre weighs 1.55g), which is finer than ramie and silk fibres, and similar to cotton and cotton-type chemical fibres. Because of the presence of high amount of hemicellulose in the fibre (Rowell, 2005), the moisture regain capacity of the Nelumbo fibre was also recorded to be 12.32% (Wang *et al.,* 2008, Pan *et al.,* 2011), which is same as ramie fibre, higher than cotton and silk, and less than that of wool. This indicates excellent absorbent quality of lotus fibre, comparable to other standard fabrics.

Further, this study also points towards the possibility of producing yarns with good strength, fineness and evenness from lotus fibres. It can be used to spin high count yarns (Wang *et al.,* 2008). In normal state, the strength of lotus fibre is greater than that of cotton and viscose fibre (Yuan *et al.,* 2012).

The percent crystallinity and preferred orientation of crystallites in the lotus fibres are 48% and 84% respectively (O'Malley, 2011). Gardetti and Muthu (2015) reported that lotus fibres have breaking tenacity and young's modulus very similar to cotton and the elongation of the lotus fibres is only about 2.6%. A later study conducted by Chen *et al.,* (2012) further reported the other properties of the lotus fibre, like its crystallinity, orientation, density, fineness, strength and breaking elongation. The lotus fibre is typically cellulose with around 48% crystallinity and 60% orientation (Chen *et al.,* 2012). The fibre also contains lignin (outer layer) and hemicellulose (between microfibrils) in high amount (Pan *et al.,* 2011). The density of fibres is 1.1848g/cm^3 and fineness is 1.55 dtex (Chen *et al.,* 2012). It has high strength and low stretchability (Only 2.75% breaking elongation) with an initial modulus of 146.81cN/dtex its breaking strength is 3.44cN/dtex (Chen *et al.,* 2012). The length-to-fineness ratio of this fibre is 10^4, which makes it an acceptable fibre for modern textile processing, for which the optimum length-to-fineness ratio should be in the range of 10^2 - 10^5 (Mu, 2013). The fibres of lotus stem can be further processed using sodium hydroxide (NaOH) that removes impurities and sodium chlorite ($NaClO_2$) which improves cellulose content in the fibres, these chemicals are reported to remove up to 91.56% impurities from

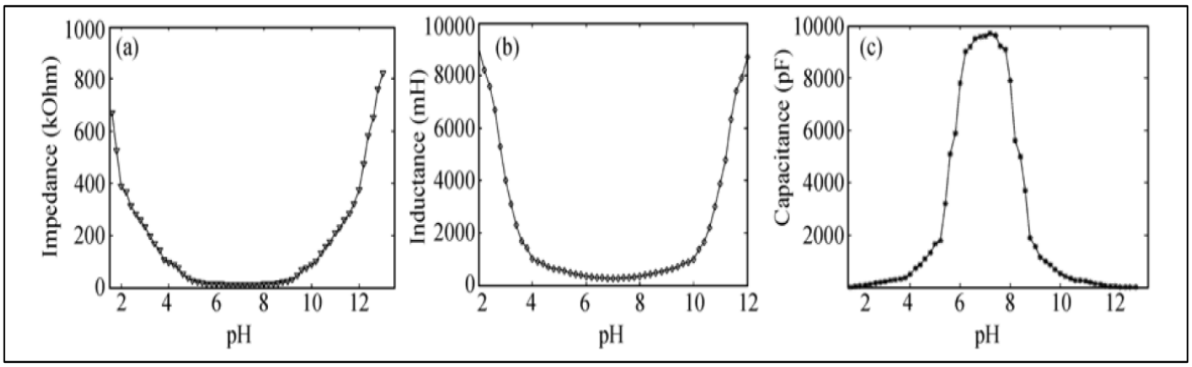

Figure 4. The impedance curve (U-shaped) (a), the inductance curve (U-shaped) (b), and the capacitance curve (Ω -shaped) (c) of lotus root silk varies with the pH value of Alcohol (Nieet al., 2008)

the fibres, this is very valuable for lotus fibres preparation on industrial scale (Cheng *et al.,* 2018). All the data mentioned above indicates that lotus fibre is acceptable for preparing clothing and garments. Studies on electrical parameters on lotus fibre dipped in liquor found

that at the pH of liquor, the inductance and impedance vary in 'U' shape curves on graph, and the capacitance varies in 'Ω' shape curve on the graph. The minimum value of the U curves and the maximum value of the Ω curve appear at the point where the pH is 7. These phenomena (figure 4) are referred as the "U or Ω effect". This actively demonstrates that the lotus fibre is perfectly bio-compatible with the human tissues. The study results may imply that the *Nelumbo* fibres have broader potential applications away from fashion industry, in biomedicine, tissue engineering, and bioelectronics (Nie*et al.,* 2008).

Extraction and processing of the lotus fibres:

N. nucifera grows very well in warm tropical climate and sometimes its seed can endure even below-freezing temperatures. 5 to 6hr of direct sunlight every day for at least 3 to 4 weeks with an air temperature of about 27 °C and warm water whose temperature ranges from 4 to 15.5 °C and in some cases up to 26.6 °C is ideal for the lotus flower to thrive. To obtain lotus stems of optimum length and quality, the harvesting must take place in the rainy season from June to November (Fraser-Lu and Ma, 2007).

After harvesting the plant, within 24 hours, Nelumbo stems/roots are lightly cut with knife such that it doesn't damage the vascular bundles and then twisted and separated to extract the fibres (figure 6). Likewise, heated silk was also obtained from lotus roots by heating them before extracting silk, in a dry oven at 100 °C for 2 hours (Zhang and Guo, 2014). Since the old times, the extracted lotus fibres are rolled into a single thread (figure 7) by a worker using his/her hand and dried by keeping them with dry maize seeds. The subsequent step is yarn preparation, where a bamboo spinning frame is used to make yarns having 40m of threads spun together. Besides the physical method of fibre extraction, which is very time-consuming (figure 5) and requires a lot of skill, an alternate and lesser skill-intensive method was proposed by Cheng *et al.,* (2017) that relies on micro waves for extraction and isolation of lotus fibres. In microwave irradiation, 5cm long pieces of dried Nelumbo stems about 2g are placed in 100ml of 0.5M NaOH solution and showered with microwaves of 2450MHz frequency 750W power for 20 mins. The Nelumbo stems were then treated with DI water (de-ionized/demineralized) to neutralize the altered pH due to the microwaves. Subsequently, the fibres were isolated from vascular bundles of the Lotus stems by hand, squeezing and rinsing them removing the stem fibres. Lastly, the fibres were dried at 50°C and the threads obtained are the raw lotus fibres/lotus silk (Cheng *et al.,* 2017). These threads are spun into

yarns and later used to make various fabrics, ranging from handkerchiefs to robes (Tomar & Yadav, 2019).

As far as the processing of lotus fibre is concerned, it is a particular skill & labour-intensive and tiresome process. It takes approximately 32,000 lotus stems to make 1.09 yards of fabric, and around 1,20,000 lotus stems must be processed for making an average garment. As mentioned earlier, lotus fabric production is very slow; it takes almost 1.5 months to make a complete lotus fabric garment. Although there is no waste as all parts of the lotus are utilized which ensures the production of a product that is entirely sustainable/ eco-friendly (Gardetti and Muthu, 2015).

Due to its highly time-consuming production, the lotus flower fabric appears as a rare and exclusive fabric. The lotus fabric shows properties like soft and comfortable to wear, especially breathable and wrinkle-free fabric, making it a suitable fabric for high-quality fashion clothing (Mahapatra, 2012).

Figure 5. Lotus fabric manufacturing process (Tomar and Yadav, 2019;

Lotus fabric and the luxury clothing:

Figure 6. Extraction of Nelumbo stem fibres

Luxury fashion played a prominent role in the social and economic order of previous centuries (Royal people and noblemen wore distinct and better clothes than the common people) and this continues to have a major impact on our modern societies and economies to this day. Within the luxury sector, luxury fashion (clothing and accessories) accounts for around $150 billion USD (Cherny-Scanlon, 2016). The luxury fashion market size was valued at $ 110.64 billion USD in 2020 and is expected to reach USD 153.97 billion by 2026 growing at a Compound Annual Growth Rate (CAGR) of 5.66%, as per "Luxury Fashion Market - Global Outlook & Forecast 2021-2026" report published in "GLOBE NEWSWIRE" (2021). Despite being very different concepts, Luxury and sustainability both have a few common features like - respect for old tradition and workmanship, the preference given to quality over quantity and the pursuit for harmony between humans and nature. According to Kleanthous, with passing time, Luxury is becoming less about exclusiveness, less wasteful, and more about enabling people to express themselves and their deepest values (Gardetti and Muthu, 2015). However, sustainability has a "status" problem in the fashion industry. On one hand, there is the mainstream, single-use "fast fashion" clothing that almost everyone is familiar with and on

Figure 7. Rolling of Nelumbo stem fibers into a single

the other hand, there is the emerging "sustainable" fashion, which still has a marginal market share and is typically considered uncool (Cherny-Scanlon, 2016).

According to Hockerts and Wüstenhagen (2010), there are two main types of brands in the sustainable textile market. First group of brands is the "Davids" and the second is the "Goliaths". The Davids, also referred to as the 'Emerging Davids', are the new emerging sustainable fashion brands in the industry. The Goliaths, also called 'Greening goliaths', are the already established major international fashion companies adopting sustainable eco-friendly clothing. (Hockerts and Wüstenhagen, 2010). Both of those mentioned above 'Emerging Davids' and 'Greening Goliaths' brand shave an extensive role in transforming the modern fashion industry to move it forward towards sustainable clothing (Hockerts and Wüstenhagen, 2010). In fact, the interaction between Davids and goliaths resembles a naturally occurring phenomenon called as "co-evolution", where each side moves the transformation forward. "Co-evolution" is a term from evolutionary biology describing the simultaneous evolution of two or more different species (in this case 'Emerging Davids' and 'Greening Goliaths') that are mutually depended on each other (Ehrlich and Raven, 1964). The David's brands have an active attitude based on a novel approach to standards to generate social and environmental changes leading to sustainability. Unlike the Goliaths, the Davids are not afraid to break the norms and promote innovative answers to environmental and social issues. Davids have less interest in the status quo and have less to lose and more credit to gain from eco-friendly innovations (Gardetti and Muthu, 2015).

In turn, the major international brands are still anchored to the usual mind-set of generating the most profit by selling the thing that sells the most. Numerous recent reports show that established fashion giants' transition towards sustainability is slow. Even though a few brands have a positive approach towards the challenge of sustainability, it is observed that, in general, the industry reacts to the market and consumers' demands (Gardetti and Muthu, 2015). Examples of these types of companies include "Loro Piana" a company based in Italy, which can be termed as a 'Greening goliath'. Another brand called Samatoa based in Cambodia, can be termed as a 'Emerging David' in terms of Hockerts and Wüstenhagen (2010).

Conclusion and some forward thinking:

The textile industry is the second-largest pollutants releasing industry globally; 20% of all freshwater pollution occurs due to textile treatment and dyeing processes. Surveys show that

textile waste is consumed nearly 5% of all landfill space. Since lotus fibre is obtained from the discarded stems of Lotus, it can help reduce waste production and aid in its management. Also, lotus fabric production will create employment opportunities for local people since it takes around 24-25 individuals to harvest the stems, fibres, and process it. Softness, exceptionally breathable, and crease-resistant properties make the lotus fabric an attractive alternative to present synthetic clothing materials. Through proper encouragement, training, and cooperation with the local population, lotus fabric can be mass-produced and popularized in India. Other than fabric production, lotus fibres also show the "U/Ω effect" because it also has possible implications beyond textile in the field of tissue engineering, regeneration, and bioelectronics.

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Remote sensing: An overview with fundamentals and applications

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Introduction:

A simple statement can derive the broad concept of remote sensing, namely, the acquisition of information from a specific distance. It is the study of measuring emitted and reflected radiation to get information about an object and phenomenon (Ray, 2013). According to Lillesand et al. (2015), The science and techniques of acquiring information about an object, land area, phenomena, or ecosystem process using a technology that is not in direct touch with the object, region, or phenomenon under research are known as remote sensing. The data collection is done remotely using various sensors, which may be further analyzed to obtain information about the objects, areas or phenomenon. Variations in force distributions, acoustic wave and electromagnetic energy distributions are only some of the types of data that may be gathered. Modern remote sensing, according to Joseph (2005), is an extension of the natural phenomena of visual perception of things. Apart from visible spectrum, the electromagnetic radiation from the ultraviolet to far infrared and the microwave regions is used for remote sensing. The observations, which are directly inferred through electromagnetic radiation (EMR) from the sun or self-emitted radiance, is called passive remote sensing. Active remote sensing, on the other hand, uses electromagnetic radiations of a given wavelength or band of wavelengths to illuminate objects and records reflected or back-scattered EMR to obtain information, such as LiDAR, RADAR, and SAR.Remote sensing is described as the process of detecting the earth's surface from space using the qualities of electromagnetic waves generated, reflected, or diffracted by detected objects in order to improve natural resource management, land use, and environmental protection. The classification of remote sensing is further based on the selection of EMR (e.g. microwave and optical) Navalgund et al. (2007). Optical remote sensing uses interference and polarization concepts with electromagnetic energy to detect the scattered energy returning from the terrain and records it as an image. Microwave remote sensing uses interference and polarization concepts with electromagnetic energy to detect the scattered energy returning from the terrain and records it as an image. The basic goal of remote sensing is to collect information about two or three dimensions of actual things in an orderly, systematic, and large-scale manner.

Through various earth observation satellite sensors, one can obtain large and broad, global coverage and repeatability of data to obtain multipurpose information, which helps in detecting things that are normally absent in visible spectra, such as land-surface temperature, underground or sub-surface water, and so on.There are several Earth Observation (EO) Satellites namely, Cartosat series, Landsat series, Sentinel 1, 2, MODIS, RISAT 1 and RADARSAT 2, Resourcesat, Envisat, Oceansat 2, IRS-1A, and many more.

Electromagnetic Spectrum:

The term "electromagnetic radiation" (EMR) refers to all of the numerous forms of energy emitted by electromagnetic processes. Electromagnetic energy comes in various forms, including visible light. Electromagnetic radiation includes radio waves, infrared light, and X-rays. The vibrations of electric and magnetic fields, which change in amplitude in a direction perpendicular to the direction of propagation of radiations at a constant speed of light (c = 3*108 m/s), generate electromagnetic waves. Figure 1 depicts a broad definition of EMR. These vary from mechanical waves in that they do not require a medium to propagate, therefore they may move through air, solid materials, and even the vacuum of space. Thus, to define the EMR scientifically, it can be said as a form of energy emitted or absorbed by charged particles which exhibits wave-like behavior as it travels through space.

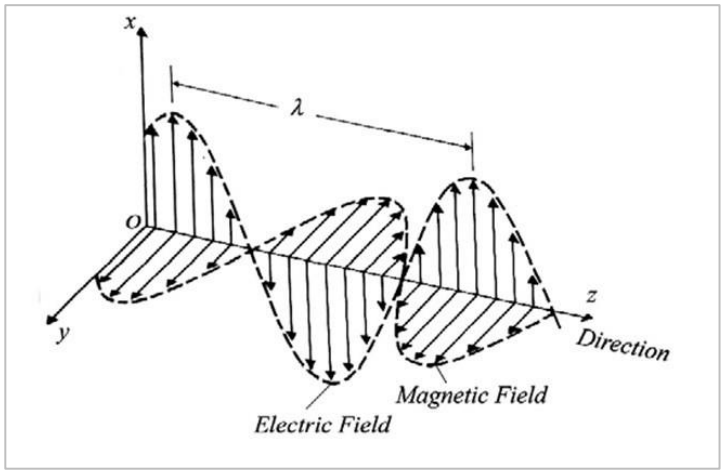


Figure 1. Illustration on the concept of EMR in which propagation of electric and magnetic field is shown

Source - http://www.fao.org/3/t0355e/T0355E02.HTM, accessed on 25th April, 2021.

The electromagnetic spectrum is the entire range of all possible frequencies of electromagnetic radiation (Figure 2). This contains electromagnetic radiation ranging from Gamma rays to radio waves, with the intensity and frequency generally decreasing as the wavelength lengthens. There are four kinds of resolution that are described from the EMR spectrum are as follows:

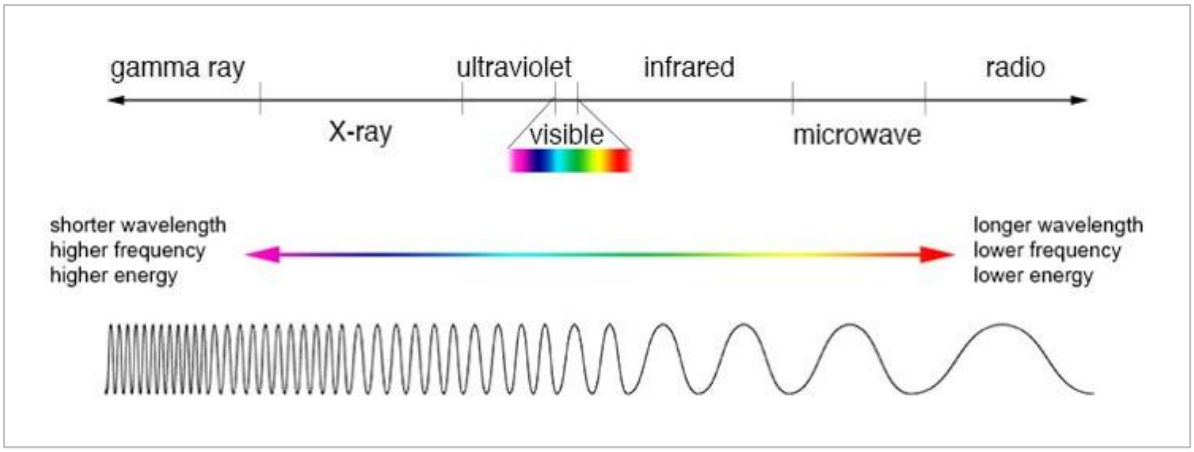


Figure 2: Electromagnetic spectrum showing waves and the radiations with respect to wavelength and frequency *Source -http://gsp.humboldt.edu, accessed on 8th April, 2021.*

1. Spectral resolution – It is the variation in the reflectance/emittance as a function of wavelength. Spectral responses are recorded by separate spectral bands such as Red, Blue, Green, Thermal, NIR, etc. A reflectance curve in Figure 3 demonstrates the spectral resolution. It is further subdivided into four classes:

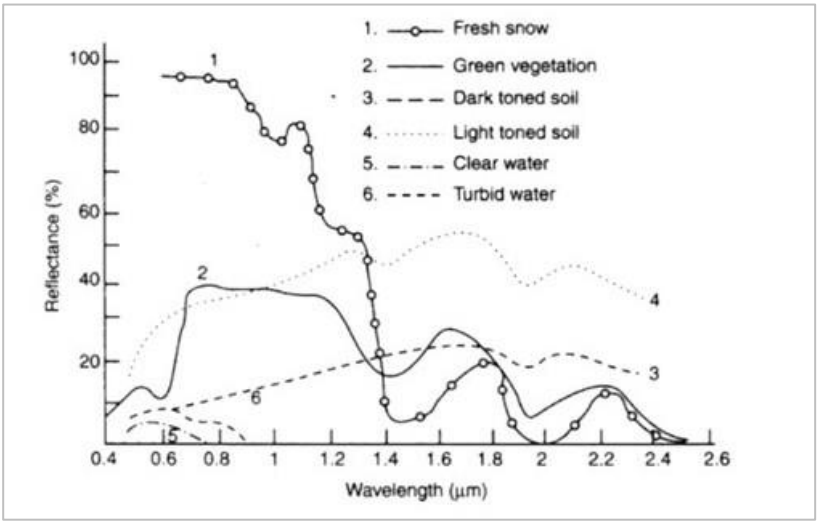


Figure 3: Spectral reflectance curve to determine spectral resolution *Source –Lillesand et al. (2015). Remote sensing and Image interpretation. 7e.*

a. Panchromatic - There is just one band (B/W) in this type of image.

b. Colour — It is made up of combinations of three visible spectrum hues (RGB)

c. Multispectral – consists of 3 to 10 bands and offers Medium level spectral resolution (Feng et al., 2020)

d. Hyperspectral – consists of 100s of band and offers higher spectral resolution (Feng et al., 2020)

Spectral indices are combinations of spectral reflectance from two or more wavelengths that show the relative abundance of a feature of interest. Vegetation indices are the most popular type, but other indices are available for burned area, built-up features, hydrologic and

geologic features. The band combinations for formulating spectral indices varies from satellite to satellite. Some of the most common spectral indices are listed in Table 1.

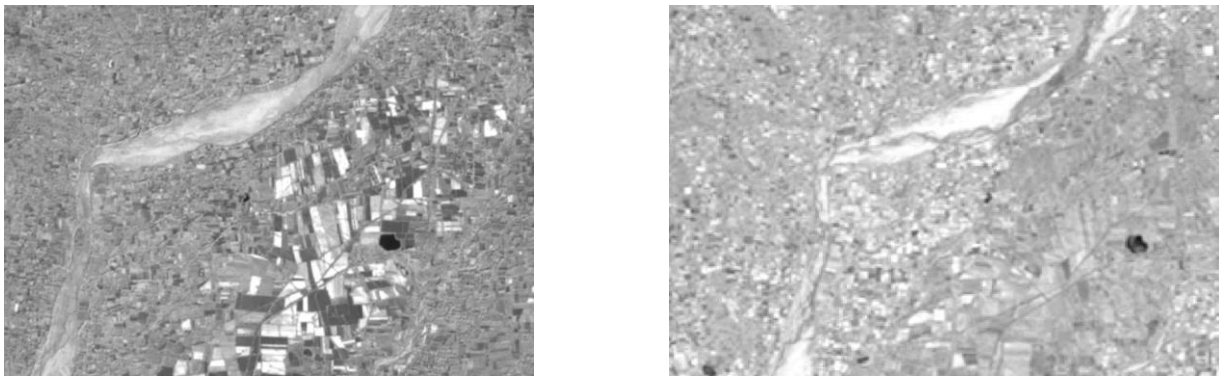
Table 1: Different kinds of Spectral indices with respect to their formulations of band combinations:

No	Spectral indices	Formulation (Band combinations)
1.	NDVI (Normalised Difference Vegetation Index)	NIR – Red / NIR + Red (Where, NIR is Near-infrared band)
2.	NDWI (Normalised Difference Water Index) NDMI (Normalised Difference Moisture Index)	NIR - SWIR / NIR + SWIR
3.	AVI (Advanced Vegetation Index)	[NIR * (1-Red) * (NIR-Red)] $^{1/3}$
4.	NDSI (Normalised Difference Snow Index)	Green – SWIR / Green + SWIR
5.	SAVI (Soil Adjusted Vegetation Index)	((NIR – R) / (NIR + R + L)) * (1 + L) Where, L is soil brightness correction factor
6.	MSI (Moisture Stress Index)	MIR / NIR Where, MIR is Middle-wave Infrared
7.	NDGI (Normalised Difference Glacier Index)	NIR – Green / NIR + Green
8.	NDBI (Normalised Difference Built-up Index)	SWIR – NIR / SWIR + NIR
9.	BSI (Bare Soil Index)	((Red + SWIR) – (NIR + Blue)) / ((Red + SWIR) + (NIR + Blue))

Source -https://giscrack.com/list-of-spectral-indices

2. Spatial resolution–As discussed in the book Advance Remote Sensing, 2012, it is defined as the smallest item that the sensor can resolve, or the ground area photographed by the ground sensor's instantaneous field of view (IFOV), or the linear dimension on the ground indicated by each pixel, in the reflectance/emittance determined by the shape, size, and texture of the target. It is measured in metres, for example (250m, 80m, 10m, 1m resolutions, etc). Figure 4 is an example of spatial resolution.

10 m resolution **30 m resolution**



(a) **(b)**

Figure 4: Example of Spatial Resolution by imagery acquired from Sentinel (a) and Landsat (b) satellite sensors

3. Temporal resolution – Temporal resolution refers to the amount of time it takes to revisit and gather data for the same place. For example, Landsat's revisit time period is 16 days, whereas Sentinel's is 10 days. The processed temporal resolution is shown in Figure 5.

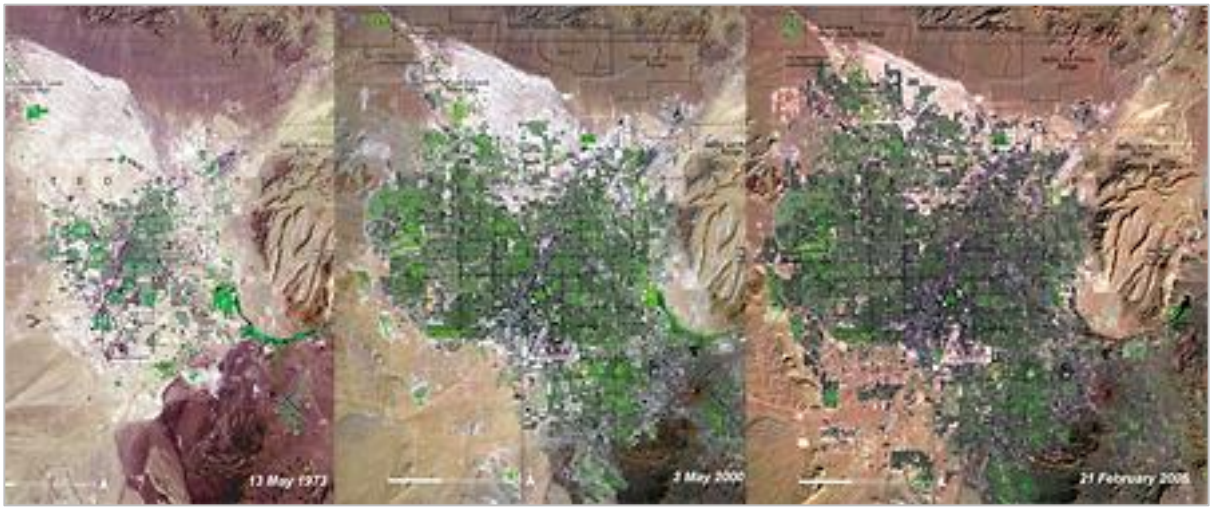


Figure 5: Example of Temporal resolution of Las Vegas over time in 1973, 2000 and 2006

Source- https://seos-project.eu/remotesensing

4. Radiometric resolution – The radiometric resolution of a picture captured by a sensor is determined by its sensitivity to the magnitude of electromagnetic radiation. The finer a sensor's radiometric resolution is, the more sensitive it is to minute variations in reflected or emitted energy it may detect.

Components and process of remote sensing:

The process of remote sensing is depicted in Figure 6. Despite the fact that the techniques for collecting, processing, and interpreting remotely sensed data vary, imaging systems must have the following components:

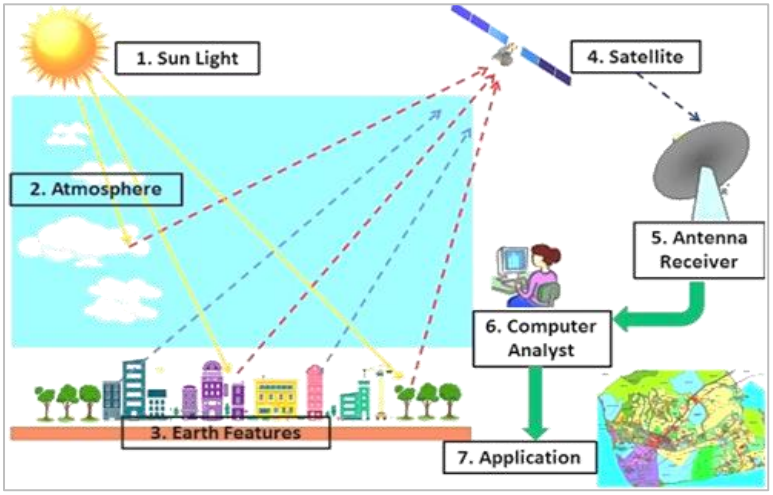


Figure 6: A generalized process components of remote sensing technology

Source - https://www.gisoutlook.com/2019, accessed on 8th April, 2021.

1. Energy source or illumination:

This is the most basic prerequisite for the remote sensing procedure, to have a source of energy that illuminates electromagnetic energy to the target of interest, for example, Active and passive sensors. Mostly the sensors are passive which tends to measure the solar radiation reflected from the target.

2. Interaction with the atmosphere:

Electromagnetic radiation must travel a certain distance through the Earth's atmosphere before reaching the surface. Particles and gases in the environment can alter incoming light and radiation, and these affects are caused via scattering and absorption processes (Figure 7).

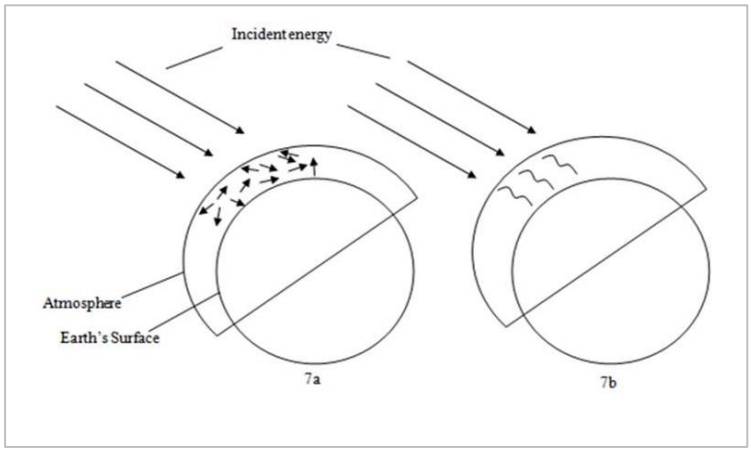


Figure 7: Interaction of EMR with atmosphere (a) Scattering and (b) Absorption

Electromagnetic radiation is diverted from its intended path when particles or large gas molecules interact in the environment. The wavelength of the radiation, the number of particles or gases, and the distance the radiation travels through the atmosphere are all considerations. There are three 3 types of scattering which take place, are described in Table 2, All the different types of scattering with examples are briefly shown in figure 8.

Table 2: Different types of scattering occurs when EMR interacts with the atmosphere:

No.	Types of Scattering	Particle size (μm)	Examples
1.	Rayleigh	< 0.1 μm	Small specks of Dust, N_2, O_2 molecules.
2.	Mie	~ 1 to 10 μm	Pollen, Smoke, Water vapour
3.	Non – Selective	> 10 μm	Water droplets and large dust particles

Source: https://www.nrcan.gc.ca/maps-tools-publications

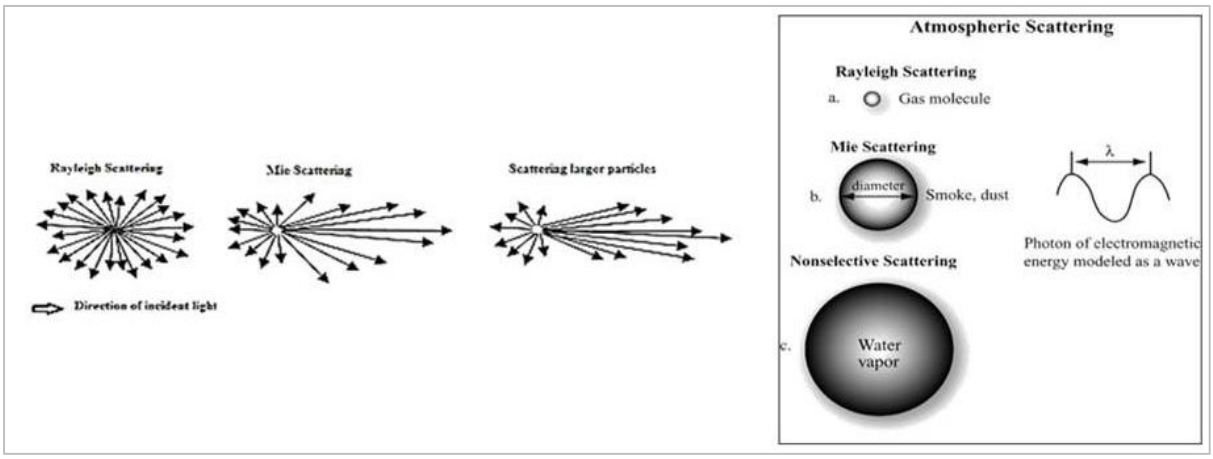


Figure 8: Different types of scattering when EMR interacts in the atmosphere or with the Earth's surface *Source - http://www.geo.oregonstate.edu/ , accessed on 8th April, 2021.*

When EMR interacts with the atmosphere, one of the key mechanisms is absorption.It causes molecules in the atmosphere to absorb a certain quantity of energy at various wavelengths, as opposed to scattering. The three primary atmospheric elements that absorb radiation are oxygen, carbon dioxide, and water vapour. Atmospheric windows are portions of the EMR spectrum that are not heavily impacted by atmospheric absorption and hence ideal for distant sensors (Figure 9). The visible portion of the spectrum, to which our eyes are most sensitive, corresponds to both, the atmospheric window and the peak energy level of the sun.

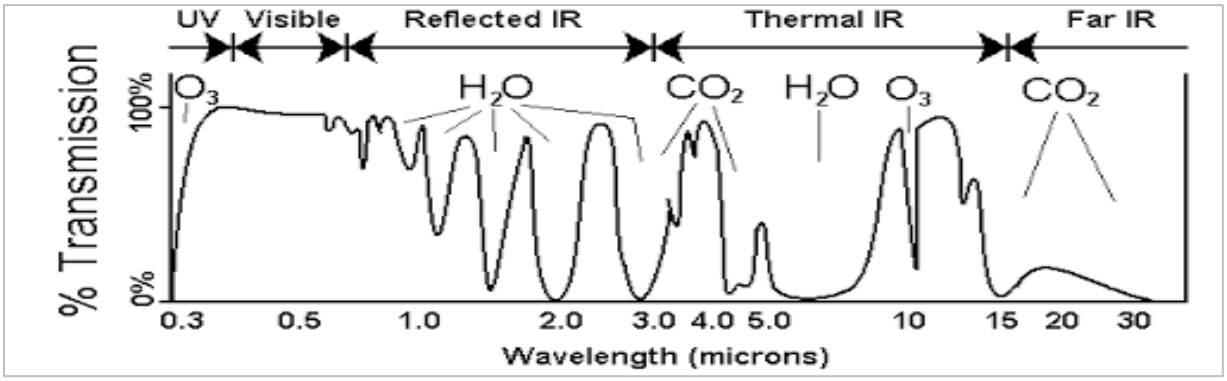


Figure 9: Atmospheric window showing the transmission of molecules at different wavelength with respect to different radiations *Source - http://www.sarracenia.com/astronomy, accessed on 8th April, 2021.*

3. Interaction with the target:

After passing through the atmosphere, the energy interacts with the target, depending on the qualities of both the target and the radiation. Figure 10 depicts some of these interactions. As the energy travels back from the target to the sensor, this might happen a second time. When electromagnetic energy collides with matter, whether solid, liquid, or gas, the following interactions are possible:

- Radiation can pass through or be transferred through the substance.
- It may be absorbed and give up its energy largely to heating the substance.
- It may be emitted as a function of its emissivityand temperature.
- It can be reflected in two different ways: specular and diffuse (Scattered).

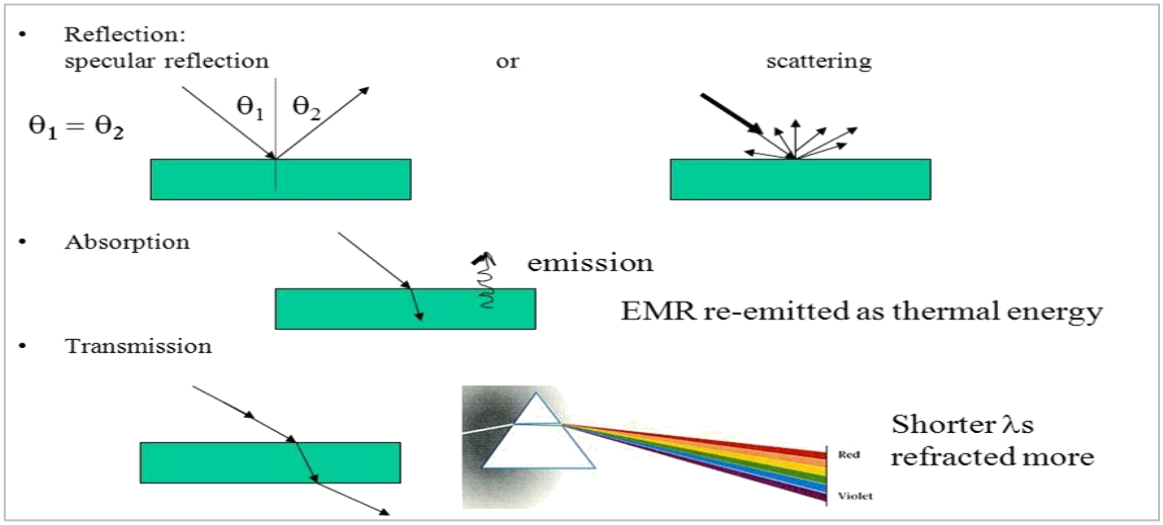


Figure 10: EMR interaction with the Earth's Surface

Source: https://www.slideserve.com/portia © Rick Lathrop, accessed on 25th April, 2021.

4. Recording of Energy by the sensor:

After the energy has been scattered by, or emitted from the earth's surface, there is a need for a sensor which is mounted on a satellite, to collect and record the EMR. The sensors are well-known for the EMR area they detect. Optical and microwave remote sensing, as well as active and passive remote sensing, are elaborated by Navalgund et al., (2007); Feng et al., (2020); Ray, (2013).The sensors that will be used to collect data must be put on a platform. This might be on the ground (e.g., portable radiometers), in the air (e.g., NASA's AVIRIS sensor on board aeroplanes), or in space (i.e., satellite based).

5. Transmission, Reception, and Processing:

The sensor's energy must be sent, usually in electronic form, to a receiving and processing station on the ground, where the data is processed and stored in digital form.

6. Interpretation and analysis:

Furthermore, this processed data is visually and digitally evaluated to derive information about the lit target. There are numerous specialised instruments or hardware and software used that are commonly known as image processing tools which involves four basic steps viz. image correction/restoration, image enhancement, image transformation and image classification.

7. Application:

When we use the extracted and processed information to solve a specific issue, this is meant as a completion of the final step of remote sensing process. This task may be performed and completed by specialists who work in each application subject.

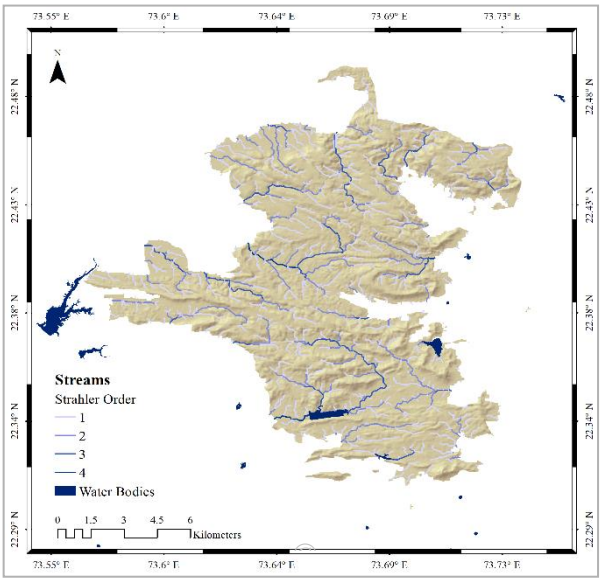
Applications of remote sensing:

Every application itself has some specific demands for spectral, spatial, radiometric and temporal resolution of the satellite sensor (Shandilya et al., 2013). Remote sensing has shown to be quite useful in understanding and resolving issues in practically all sectors in the contemporary period. In this article, we'll look at a handful of its most common applications in the modern day.

1. Geology:

In the field of geosciences, the remote sensing techniques are applied to interpret and analyse the bedrock, lithological, structural formations, sedimentation, (Merritt et al., 2014; Stead et al., 2019) planetary, surface monitoring, (Clark et al., 2003; Des Marais et al., 2002; Shepard et al., 2001) geo-hazards and mineral exploration through observation and modelling techniques.

2. Hydrology:



Some examples of applications of remote sensing in hydrological science include, soil moisture estimation, flood and wetland monitoring, watershed and drainage modelling, river delta change detection, and many. Figure 11 and 12 are an example of one of the studies undertaken for hydrological modelling and mapping of wetlands, respectively (Dharaiya, 2020a; Dharaiya et al., 2021).

Figure 11: Drainage modelling in Jambughoda Wildlife sanctuary, Gujarat (after Dharaiya, 2020a)

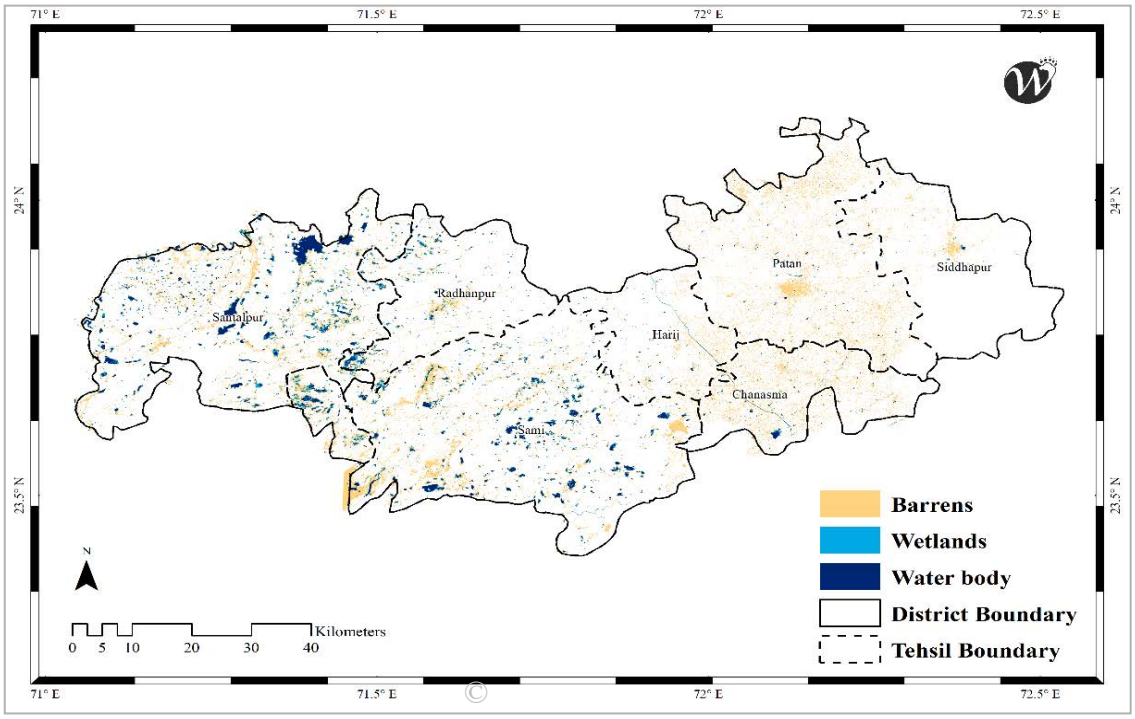


***Figure 12: Mapping of wetlands in Patan district, Gujarat (Dharaiya et* al., 2021)**

3. Glaciology:

By means of remote sensing, one can acquire information and map the ice concentration, ice type or motion (Frey et al., 2014; Jiyang Chen & Ohmura, 1990), iceberg detection, glacier dynamics (Pratibha & Kulkarni, 2018; Remya et al., 2019), snow thickness monitoring (Gantayat et al., 2014; Kulkarni et al., 2002), meteorological change research, snow-water equivalence, snowmelt run-off estimation and many more.

4. Agriculture:

Remote sensing is commonly utilised as a decision-making tool in agriculture, such as for crop type classification, crop condition evaluation, crop yield estimation, soil characteristics, soil management methods, and compliance monitoring (Zheng et al., 2014).

5. Forestry:

Forestry is one of the major sectors where remote sensing has proved as very effective tool. Some of the purposes that can be reached include reconnaissance mapping, commercial forestry, and environmental monitoring, all of which contribute in the management and conservation of natural resources. Figure 13 is an example of mapping the forest coverat Ratanmahal wildlife sanctuary, Gujarat, using spectral indices.

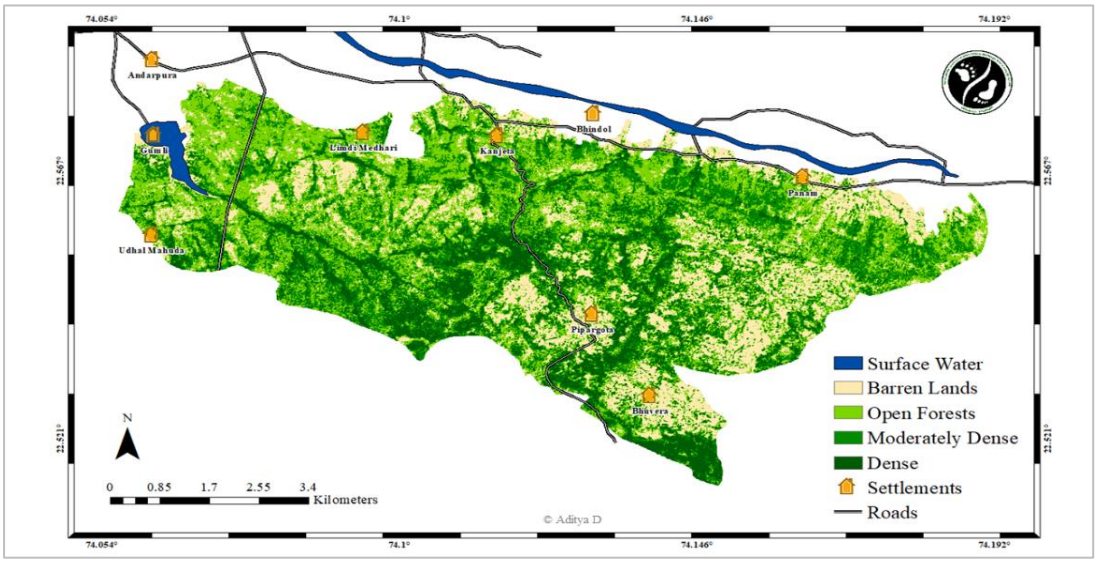


Figure 13: Forest cover map of Ratanmahal wildlife sanctuary, Gujarat *© A. Dharaiya*

6. Land use Land cover (LULC):

Yacouba et al. (2010) examined the LULC using two terms: "land use," which refers to the purpose for which the land is used, and "land cover," which refers to the natural surface cover on the ground. It's commonly utilised in habitat and natural resource management, urban development, baseline mapping, risk assessment, legal borders for tax appraisal, and change detection, among other applications. Figures 14 and 15 show the LULC categorization and wetlands change detection, respectively (Dharaiya, 2020b; Dharaiya et al., 2021).

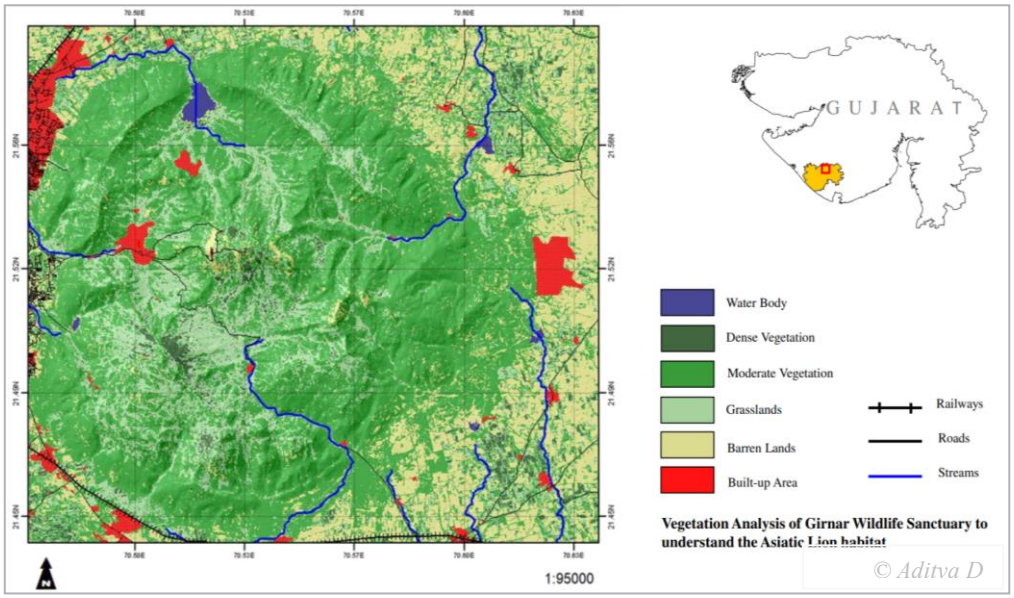


Figure 14: LULC classification with vegetation cover in Girnar Wildlife sanctuary, Gujarat (Dharaiya, 2020b)

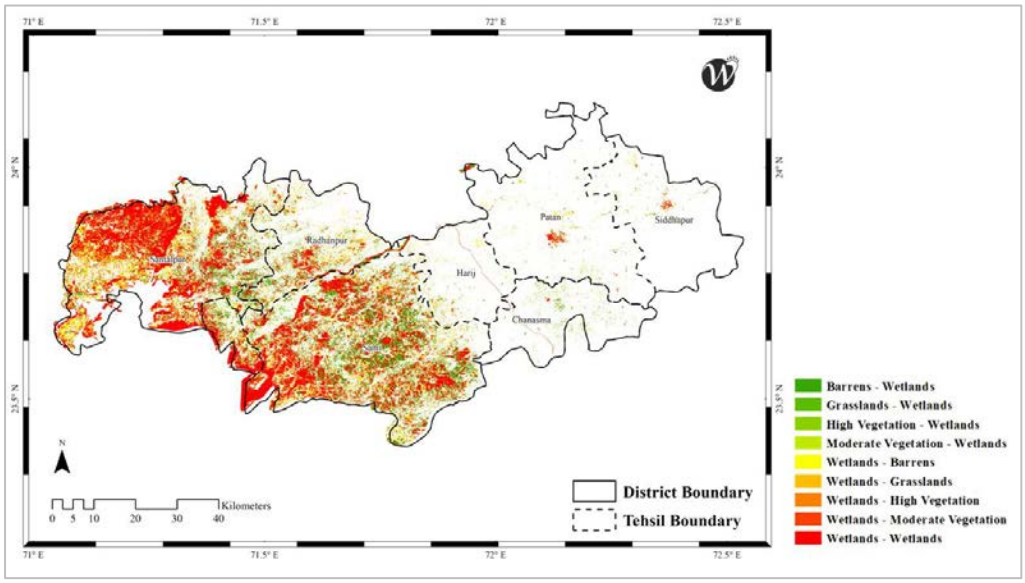


Figure 15: Change detection of wetlands in Patan district, Gujarat using Landsat 8 OLI (Dharaiya et al., 2021)

7. Coastal monitoring:

Remote sensing can be used to gather information about oceanic processes (physical and biological), oil spill (Alesheikh et al., 1997; Fingas & Brown, 1997), and shipping by means of remote sensing.

Several other applications according to Shandilya et al., (2013) include planimetry or land surveying using very high spatial resolution satellites (30cm). Using radar interferometry, radargrammetry, and photogrammetry, elevation profiles are generated by creating Digital Elevation Models (DEMs) using remote sensing data. Base map imagery gives a priori information about the regions that may be used to derive planimetric details about mineral exploration activities, topographic mapping, and surface monitoring.

Conclusion:

Remote sensing is a new method that may be used to monitor the Earth's surface. Its applications have grown in scope, allowing users to gather, evaluate, and edit data over large areas. Multi-temporal satellite data helps in the delineation of changes to the earth's surface, making it a valuable and practical tool for all users, since it improves the precision, efficiency, and quality of the analysis, making it beneficial in the decision-making process. Furthermore, the products may be utilised by other scientists, even if they are unfamiliar with the technique, to extract the highest amount of detail possible.

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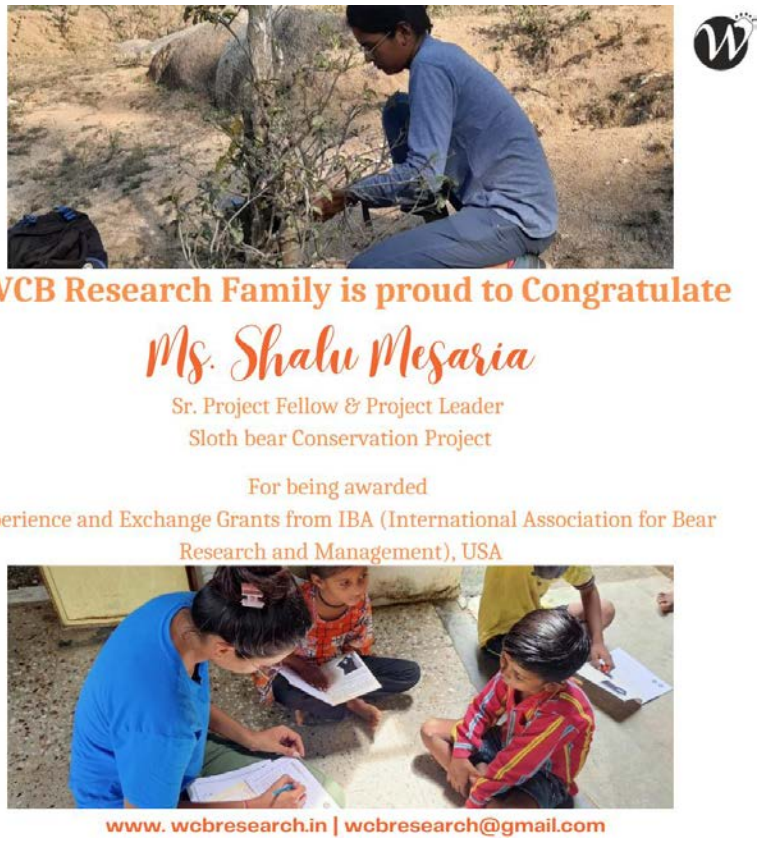

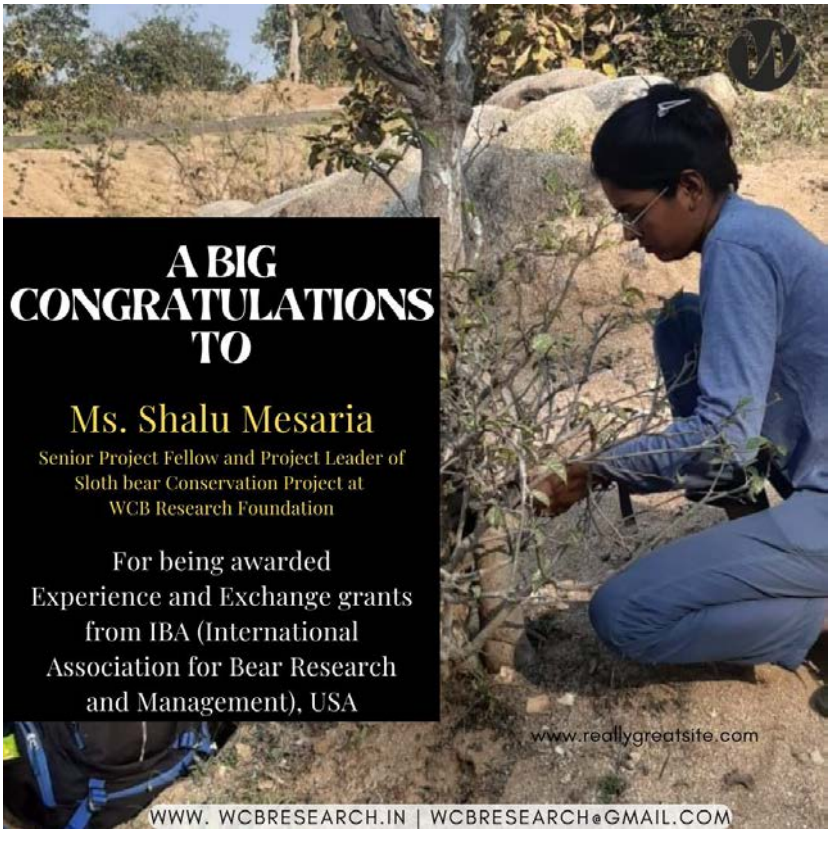

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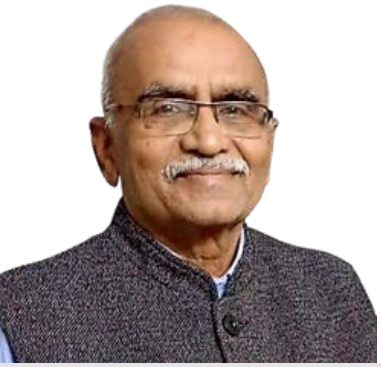

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