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SPATIAL FOREST HEALTH MONITORING USING GEOSPATIAL TECHNIQUE: A CASE STUDY OF CHANGA MANGA FOREST, PAKISTAN

MUHAMMAD ASAD
Department of Irrigation & Drainage, University of Agriculture, Faisalabad, Punjab, Pakistan.

NALAIN E MUHAMMAD
Department of Irrigation & Drainage, University of Agriculture, Faisalabad, Punjab, Pakistan.
Department of Water Resources Engineering and Management, NICE, NUST, Islamabad.

MUHAMMAD SAFDAR *
Department of Irrigation & Drainage, University of Agriculture, Faisalabad, Punjab, Pakistan.
Agricultural Remote Sensing Lab (ARSL), University of Agriculture, Faisalabad, Punjab, Pakistan.
*Corresponding Author Email: Safdarsani4340@gmail.com

MUHAMMAD JEHANZEB MASUD CHEEMA
Department of Irrigation & Drainage, University of Agriculture, Faisalabad, Punjab, Pakistan.

HAMZA FAROOQ GABRIEL
Department of Water Resources Engineering and Management, NICE, NUST, Islamabad.

UZAIR ABBAS
Agricultural Remote Sensing Lab (ARSL), University of Agriculture, Faisalabad, Punjab, Pakistan.

REHAN MEHMOOD SABIR
Department of Irrigation & Drainage, University of Agriculture, Faisalabad, Punjab, Pakistan.
Agricultural Remote Sensing Lab (ARSL), University of Agriculture, Faisalabad, Punjab, Pakistan.

Abstract

Forests play a significant role in the healthy environment of a country. Global warming, climate change, and human activities are affecting the forest cover of Pakistan. Moreover, overall forest health is also deteriorating. It is very tough to measure and monitor forest health by field survey. Forest healthdamage which is affected by water stress, different diseases, and other causes is mostly and easily observable from long distances. In this research study, we have investigated forested areas byalternative ways of making spatial forest maps by using remote sensing and GIS tools. Satellite images of July 2018 from Sentinel-2 have been used for this research study. Firstly, a forest cover map is made and evaluated by classification of Changa Manga (total area 52.7km2) Forest. Forest health is assessed using Vegetation Indices (VIs), which use specific relationships to distinguish changes in greenness, water content, and light use efficiency of the forest. After Evaluating NDVI, NDWI, and NDPI,we have 54.69%, 53.76%, and 42.45% area was healthy forest respectively. Then unhealthy forests cover 44.98%, 38.99%, and 50.21% of the area respectively. These vegetation indexes use reflectance at different wavelength bands. Different GIS tools for data acquisition were used and spatial maps of forest health were constructed for visual understanding. Our results will help forest agencies carry out necessaryreforestation plans and manage standing forests more effectively.

Keywords: Forest Health, NDVI. NDWI, NDPI.

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1. INTRODUCTION

Forests, defined as landscapes with at least 5m tall trees, provide revenue to around one billion people and employment to people worldwide. They play a crucial role in maintaining a healthy atmosphere, promoting soil conservation, watershed management, and protection against floods and landslides. Forests also impact indigenous and global environments and climate change. Forests worldwide are being severely impacted by population growth, human activities, deforestation, air pollution, and climate change. In Pakistan, deforestation rates are increasing annually, primarily due to urbanization, farming, and tourism development. This leads to flooding, desertification, and wildlife damage, posing significant threats to the environment.

Forest Health Monitoring (FHM) is a crucial part of managing and preserving forest ecosystems. To evaluate the state of forests, identify changes with time, and pinpoint possible risks like pests, diseases, and the effects of climate change, it entails the methodical gathering and analysis of data *(Stone & Coops, 2020).* FHM utilizes comprehensive monitoring methods to detect possible hazards to forests, monitor alterations over time, and provide insights for management plans that guarantee the preservation and sustainable utilization of forest resources *(Bennett & Tkacz, 2008).*

FHM has been transformed by modern technologies like Geographic Information Systems (GIS) and remote sensing, which allow for more thorough and accurate monitoring *(Fassnacht et al., 2016).* Large-scale geographical coverage offered by satellite photography makes it possible to identify indications of forest health over vast distances *(Wulder et al., 2012).* GIS tools help forest management decision-making processes by facilitating the integration as well as evaluation of spatial data. *(Myeong et al., 2006).* Monitoring forest health can support conservation and sustainable forest management by utilizing these tools. *(Goetz et al., 2015).* Our ability to adapt to environmental concerns is improved when we can follow developments in forest health through the integration of GIS and satellite data.

Effective forest management relies heavily on spatial monitoring as it makes it possible to gather and analyze extensive data across wide regions. By offering information on habitat health, biodiversity, as well as the overall ecological state of forests, this data helps decision-makers make better choices *(Lechner et al., 2020),* Without this kind of geographical understanding, attempts to manage forests could not be as precise in addressing issues like climate change as well as human encroachment *(Massey et al., 2023).*

Due to its ability to provide precise and in-depth data on the state of forests and their temporal variations, spatial monitoring is an essential component of forest management. This method collects and analyzes spatial data using technologies like GIS and remote sensing, which makes it possible to evaluate the effects on the environment, biodiversity, and forest health. *(Turner et al., 2015).* Managers can identify early indicators of disease, deforestation, and degradation by tracking and mapping forest areas, which allows for

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prompt responses. *(Hansen et al., 2013).* Additionally, spatial monitoring contributes to sustainable management of resources by facilitating the efficient planning and execution of conservation initiatives. *(Nagendra & Ostrom, 2012)*. It also makes it easier to assess the benefits of ecosystem services provided by forests for biodiversity, the water cycle, and climate regulation. (Bradshaw et al., 2009). Therefore, for long-term forest sustainability and well-informed decision-making, spatial monitoring is essential. *(Lechner et al., 2016).*

GIS and satellite photos are crucial in environmental research for monitoring and assessing ecological changes, particularly in tracking deforestation, urbanization, and climate change consequences, as they provide comprehensive and up-to-date geographical data *(Wulder et al., 2012).* These technologies contribute to biodiversity conservation through threat assessments, species distribution studies, and habitat mapping. *(Turner et al., 2015).* GIS and satellite photography are vital for monitoring and maximizing land use, as they enhance our understanding and capacity to manage environmental systems, thereby enhancing our environmental management capabilities. *(Tortora et al., 2011).*

This research uses Vegetation Indices (VIs) to assess forest health using remote sensing. Greenness VIs measures the greenness of vegetation, based on chlorophyll concentration and canopy area effects. They focus on red and near-infrared regions, with lower values indicating declining forest health. The Normalizes Difference Vegetation Index (NDVI) is used to estimate greenness VI. If the value of greenness is lower than the previous time, it indicates declining forest health. (*Nguyen et al., 2020*). NDVI is extensively used worldwide, and it is important VI to estimate healthy vegetation. This is used to measure the reflectance of green vegetation.

This is a comparatively easy index and uses visible red and near-infrared reflectance values. Water content VIs is a crucial property of forest health, determining or approximating water content in vegetation canopy for optimal growth of trees. The Normalized Difference Water Index (NDWI) is a tool used to estimate canopy water content and vegetation deviations, but it uses two different reflectance bands and estimates marginally different water properties *(Ashok st al., 2021).*

The vegetation index, Light use efficiency VIs, measures the effectiveness of vegetation in using incident light for photosynthesis, affecting growth rate and carbon uptake. The Normalizes Difference Pigment Index (NDPI) approximates Chlorophyll pigment in vegetation, crucial for photosynthesis and allowing plants to absorb sunlight energy *(Qin et al., 2021).*

This research utilized satellite images from the Sentinel-2 satellite, an Earth-observing satellite with high spatial resolution and multi-spectral data from 13 bands. The satellite, manufactured by the European Space Agency (ESA), was free of cost. The images of Changa Manga Forest were classified into five main classes: dense forest cover, light forest cover, land use or buildings, barren land, and water bodies. The classification was

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done using supervised classification with training pixel values, with the correct classification indicating the types within the image data. The research study aims to map forest health using remote sensing and GIS techniques, identifying healthy and unhealthy forest vegetation and creating visual representations. The main objectives are to protect existing forests and promote reforestation, using vegetation indices and practices to differentiate between healthy and unhealthy forest vegetation. To determine forest land cover using satellite-based imagery of forested areas. To spatially map forest health and detect forest changes.

2. MATERIALS AND METHODS

The material and methodology of performing this research study are divided into several parts.These are explained below:

2.1 Description of the Study area

Changa Manga is one of the oldest and largest man-made forests, which includes a wildlife preserve, it is around 80 kilometers southwest of Lahore. It is one of the wonderful places which Pakistan. This forest was implanted in 1890 by the governing British administration. Presently, it is preserved and looked after by the Punjab Forest Department. Changa Manga Lush green forest, the major effort of the human planting.

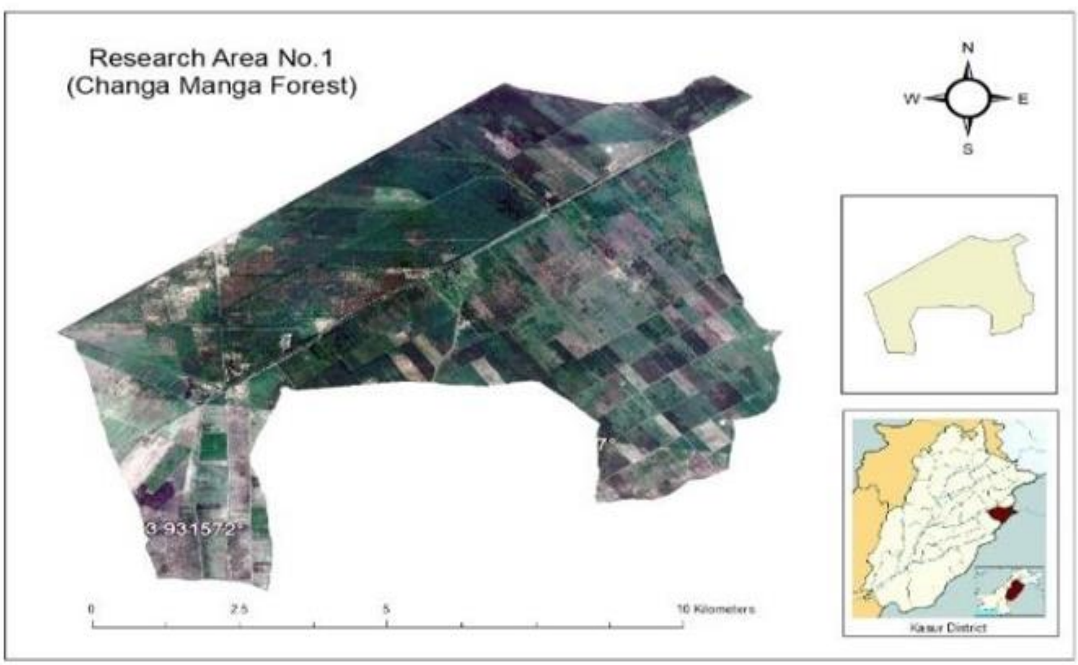

Fig 2.1: Map of Research Study Area

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2.2 Data Sources

Data are opinions that we make for monitoring the actual world and it is composed of facts or indications that might be treated to give them significance. For this research, data was attained from different sources, namely from Satellite images and from the Punjab Forest Department.

- **Satellite Data**

Earth-orbiting satellites have the potential to sight and internment massive regions of terrestrial in one image, The advantage of satellites is they go back to a similar place point above the Earth's surface at some adjusted period like Sentinal-2 return time is 5 days (Pesaresi et al., 2016). Earth-orbiting satellites had spectral sensitivities in the visible, NIR, and thermal-IR regions of the EMS (Gao et al., 2015). Sentinel-2 is an Earth surveillance satellite that can provide high spatial resolution (10 to 60 meters) imagery above land. For this purpose, the sentinel-2 satellite's images are downloaded from the United States Geological Survey (USGS) Earth Explorer's official website (http://earthexplorer.usgs.gov/). For Changa Manga Forest, the sentinel-2 tile, ID of tile is T43RCQ, was downloaded for the date of 05-06-2018

2.3 Image Analysis Software

In remote sensing, the usage of the software as a tool for image study is necessary. The most popularimage analysis and processing software is ArcGIS. It is a software package for geographic informationsystems, which is being used for many different purposes including image processing of georeferenced data and maps (Shao, et al, 2017).

2.4 Forest Cover Classification and Mapping

The association of RS and GIS for forest cover mapping offers a standing representation of land cover. Forest cover maps function as a standard towards which in future changes in them may be measured and calculated (Mayaux, et al., 2005). Hence, for forest cover mapping we performed image classification.

- **Image Classification**

In this research, we classified satellite images of 2018 our study area into five main classes such as denseforest cover, light or normal forest cover, land use or buildings, barren land, and water bodies. For classification, we use supervised classification with training pixel values. Correct classification can outcome classes that signify our categories inside the image data (Russell et al., 1995). We classify our area into five classes. The classification tool gives training samples to every class and then classifies the map with a supervised classification option. After that save the training sample files as signature files. Then again classify the image with maximum likelihood classification to get count values for each class. Then we can count the area of every class in square kilometers with a field. In the attributes table.

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2.5 Forest Health Assessment

The study objective of assessment of forest health was accomplished using multispectral spatial data of our study areas from Sentinel-2 Satellite. By this assessment, we can distinguish between the healthy and unhealthy parts of the forest. In this research, we used different vegetation indices for forest health estimation.

2.5.1 Greenness Vegetation Indices

Greenness VIs primarily measure the magnitude of greenness in vegetation like forests. This focus is on determining the reflectance of red and near-infrared (NIR) regions (Jiang et al., 2006). If the value of greenness is lower, then it means that forest health is declining and vice versa.

➢ **Normalized Difference Vegetation Index (NDVI)**

NDVI is extensively used worldwide and it’s an important VI to estimate healthy vegetation. This is used to measure the reflectance of green vegetation. NDVI is an estimation of vegetation health founded on what way a plant reflects light at explicit frequencies (Jiang et al., 2006). NDVI is defined with the following equation:

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

Where the ρ denotes reflectance at the wavelength band.

To design, the NDVI differs between -1 and +1 (Crippen, 1990). In sentinel-2 imagery band number 8 represented the NIR and band number 4 as the red VIS.

$$NDVI = {band\ 8 - band\ 4}/{band\ 8 + band\ 4}$$

Our objective was to determine the healthiness of our study area imagery of 2018 for both areas and that is why needed to find NDVI values. Firstly, entered the required bands in the software which are band number 4 represents the Red visible reflectivity, and band number 8 near-infrared reflectivity.

From the Arc Toolbar in software, find the raster calculator tool put the NDVI formula in the calculator, and then it gives the values ranges of NDVI. After analyzing the healthy and unhealthy forest in the study area, we classify the ranges of NDVI.

Figure 2.2 shows the raster map of our study area to NDVI value ranges. In these ranges, it shows the very healthy, moderately healthy, and unhealthy forests of the study area which are the Changa Manga and Mitha Tiwana forests.

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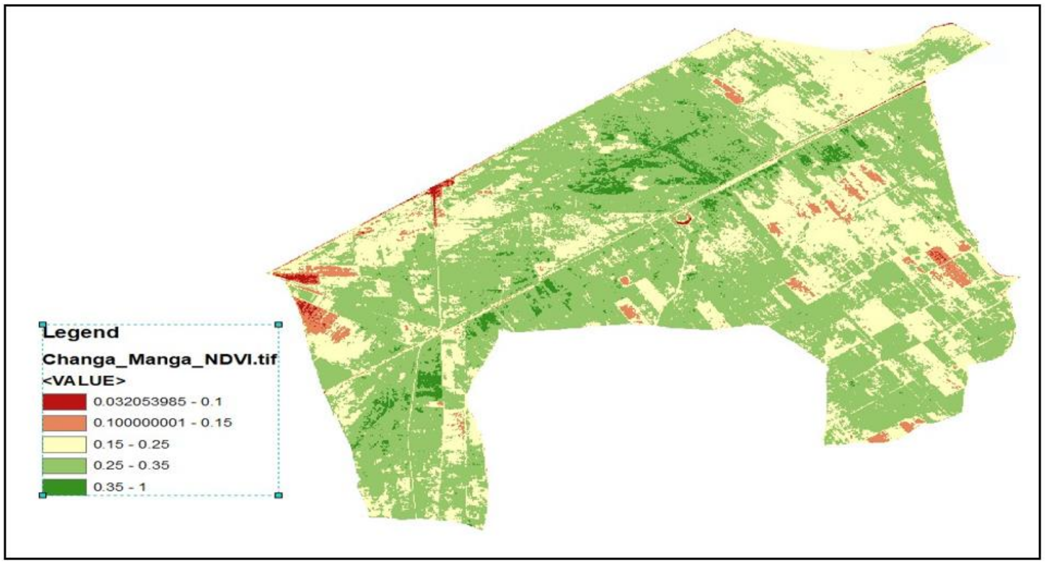

Fig 2.2: NDVI Value Ranges Raster Map of Study Area in ArcGIS

Then for our area, it needs to check how many areas in the forest are healthy and unhealthy, for that we do a supervised classification of the study area to NDVI values. After saving the signature file, apply maximum likelihood classification to get the area count of classes. We made five classes of NDVI value ranges which show the amount of healthy and unhealthy forest.

2.5.2 Water Content Vegetation Indices

Water content VIs is used in determining or approximation of water content in the canopy of vegetation. It is a significant property of forest health because trees need water for optimal growth. The Normalized Difference Water Index (NDWI) is recognized to be intensely associated with the plant water content and it is a decent substitution for plant water stress (Gao, 1995).

- **Normalized Difference Water Index (NDWI)**

NDWI also determines the deviations in the canopy water content of vegetation. NDWI is defined with the following equation:

$$NDWI = {\rho_{NIR} - \rho_{SWIR}}/{\rho_{NIR} + \rho_{SWIR}}$$

Where the ‘ρ’ denotes reflectance at the wavelength band.

The NDWI is the resultant index from the Near Infrared (NIR) and Short-Wave Infrared (SWIR) wavelength bands (Ceccato et al. 2001). The outcomes of NDWI can be obtainable in the procedure of Maps and graphs provide statistics on the spatial

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distribution of water stress on vegetation. In sentinel-2 imagery band number 8a represented the NIR and band number 11 as the SWIR (Pullanagari, 2018).

$$NDWI = {band\ 8a - band\ 11}/{band\ 8a + band\ 11}$$

Our objective was to determine the healthiness of our study area for vegetation water contents and that is why needed to find NDWI values for both areas. Firstly, after adding the image, we selected the Raster Calculator tool from the Arc Toolbar software, then put the NDWI formula in the calculator and calculated the result.

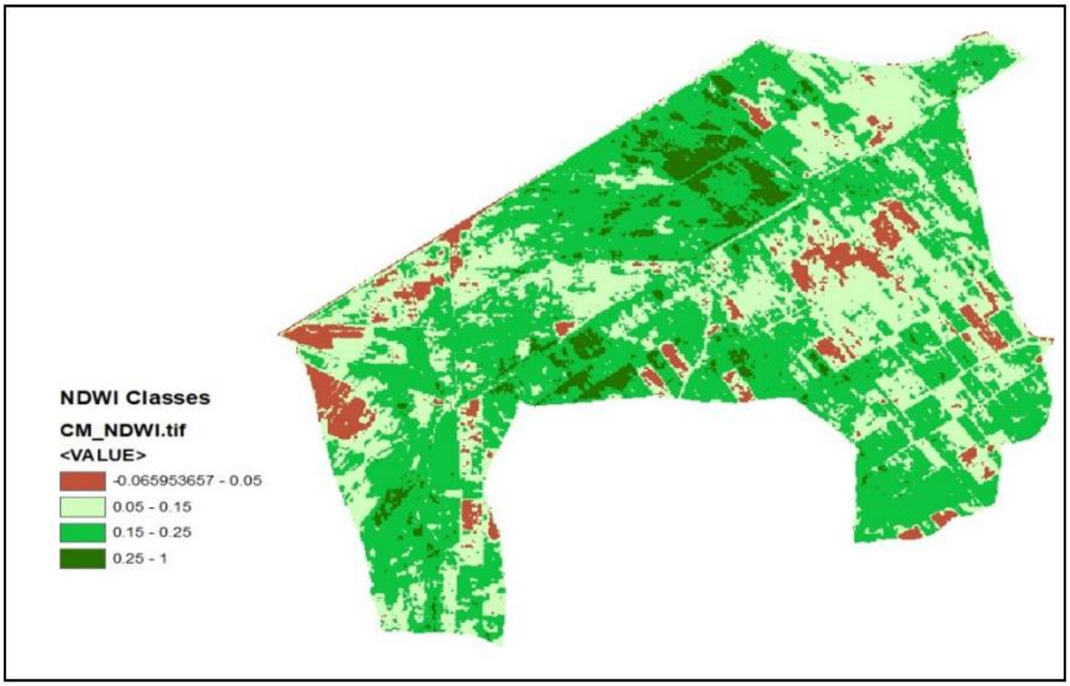

Fig 2.3: NDWI Value Ranges Raster Map of Study Area in ArcGIS

After analyzing the healthy and unhealthy forests in the study areas, we classify the ranges of NDWI. Figure 3.3 shows the raster map of the study area for NDWI value ranges. These ranges show the very healthy, moderately healthy, and unhealthy forests of Changa Manga. Then it needs to check how much areas in the forest are healthy and unhealthy for water content or NDWI, we apply maximum likelihood classification to get the area count of classes.

2.5.3 Light Use Efficiency Vegetation Indices

Light use efficiency VIs is mostly used for measurement of the effectiveness by which the vegetation uses the incident light for the photosynthesis process. Chlorophyll is essential in photosynthesis invegetation leaves (Ustin et al., 2009).

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➢ Normalized Difference Pigment Index (NDPI)

NDPI is used to approximate Chlorophyll pigment in the vegetation which is important in photosynthesis, allowing plants to absorb energy from sunlight (Penuelas et al., 1995). NDPI is definedwith the following equation:

$$NDPI = {\rho_{NIR} - \rho_{BLUE}}/{\rho_{NIR} + \rho_{BLUE}}$$

The NDPI shows us healthy or unhealthy forest vegetation as chlorophyll pigment in the trees. In sentinel-2 imagery band number 8 represented the NIR and band number 2 as the Blue (Lea et al. 2017).

$$NDPI = {band\ 8 - band\ 2}/{band\ 8 + band\ 2}$$

In this index, our objective was also to estimate the healthiness of our study area for vegetation chlorophyll pigment contents and that is why needed to find NDPI values for both areas. We determined it with the Raster Calculator tool from the Arc Toolbar software, then put the NDPI formulain the calculator and got the NDPI calculated image.

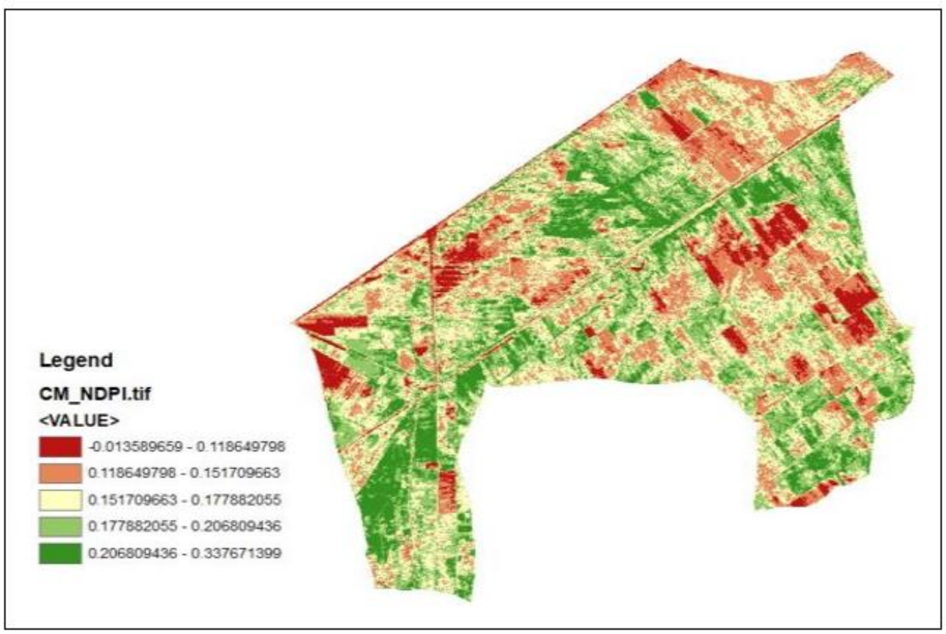

Fig 2.4: NDPI Value Ranges Raster Map of Study Area 1 in ArcGIS

Then again for our areas, it needs to check how much areas in the forest are healthy and unhealthy for chlorophyll pigment content or NDPI, for that we apply maximum likelihood classification to get the area count of classes. Then four range classes of NDPI value ranges show the amount of healthy and unhealthy forest.

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3. RESULTS AND DISCUSSIONS

3.1 Forest Cover Analysis

For forest cover analysis we classify our study area imagery of July 2018 into numerous major classes byusing a supervised classification technique. The area of each class and percentage distribution is calculated as shown in table 3.1.

Table 3.1: Changa Manga Forest Classes with Area Distribution

Value	Features	Pixel Count (m)	Area (km^2)	Area (%)
1	Dense Forest Cover	104626	10.46	19.86
2	Light or Normal Forest Cover	342705	34.27	65.05
3	Land Use or Buildings	24739	2.47	4.70
4	Barren land	53795	5.38	10.21
5	Water Bodies	1008	0.10	0.19
Total			52.69	100.00

The total area for Changa Manga Forest is around 52.7 km^2 and after applying classification, the distribution chart as shown in figure 4.1, shows that the dense forest covers 10.46km^2 (20%), light or normal forest covers 34.27km^2 (65%), land use or building covers 2.45km^2 (5%), barren land covers 5.38km^2 (10%) and water bodies covers 0.1km^2 (0.2%) of the whole area respectively. The forest cover map of Changa Manga Forest classification is made in the ArcGIS software as shown in Fig. 3.2. For this area, we classify the imagery of July 2018, and this forest cover map functions as the standard towardswhich future changes may be measured and calculated. Additionally, it eases to support andset up forested areas that are necessary to be observed for change. The spatial dissemination of vegetation cover is mostly depending on topographic and ecological features (Wang et al., 2012).

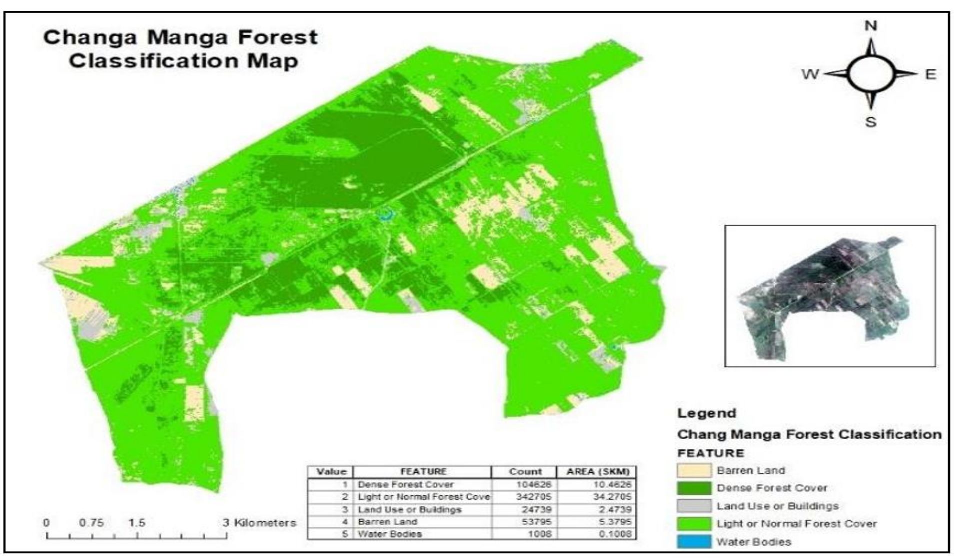

Fig 3.1: Changa Manga Forest Cover Map of 2018

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3.2 Forest Health Analysis as NDVI

The NDVI varies between -1.0 and +1.0. We perform NDVI analysis on our imagery of the study area of the year 2018. After analyzing the healthy and unhealthy forest, we classify the ranges of NDVI asshown in table 3.2.

Using the Normalized Difference Vegetation Index, the table presents a quantitative evaluation of the health conditions inside Changa Manga Forest (NDVI). A popular metric for evaluating the health and vitality of plants is the NDVI.

Ranges of the NDVI and Forest Health Five classifications are created from the NDVI data, each of which represents a distinct degree of vegetation health and cover: Zones with the highest density and quality of vegetation are classified as Very Healthy Forests (NDVI 0.35 - 1).

Forests with moderate vegetation cover and health are classified as moderately healthy (NDVI 0.25–0.35).A forest that is unhealthy (NDVI 0.15–0.25) is one that shows indications of stress or deterioration. Soil or barren land (NDVI 0.1–0.15): Low-lying areas covered with plants. Buildings or Water (NDVI -1 - 0.1): Generally covered by built-up regions or bodies of water, these are areas devoid of vegetation.

Table 3.2: Changa Manga Forest NDVI Ranges with Area Distribution

Value	Features	NDVI Value Range	Area (km^2)	Area (%)
1	Very Healthy Forest	0.35 - 1	3.11	5.90
2	Moderately Healthy Forest	0.25 - 0.35	25.69	48.79
3	Unhealthy Forest	0.15 - 0.25	22.11	41.98
4	Barren Land or Soil	0.1 - 0.15	1.61	3.06
5	Buildings or Water	-1 - 0.1	0.13	0.26
Total			52.66	100.00

The total area for Changa Manga Forest is around 52.7km^2 and after analysis, NDVI, the distribution chart as shown in figure 4.3, shows that the very healthy forest ranges 0.35-1 covers 3.11km^2 (6%), moderately healthy forest ranges 0.25-0.35 covers 25.69km^2 (49%), unhealthy forest ranges 0.15-0.25 covers 22.11km^2 (42%), barren land ranges 0.1-0.15 covers 1.61km^2 (3%) and buildings or water bodies ranges -1-0.1 covers 0.13km^2 (0.2%) of the whole area respectively.

Changa Manga Forest's health state is mixed, according to the data. While a sizeable fraction (54.69%) is categorized as extremely healthy and moderately healthy, a sizeable chunk (41.98%) is considered unhealthy.

Furthermore, just 0.26% of the forest is made up of structures or bodies of water, and roughly 3.32% of it is made up of bare ground or dirt.

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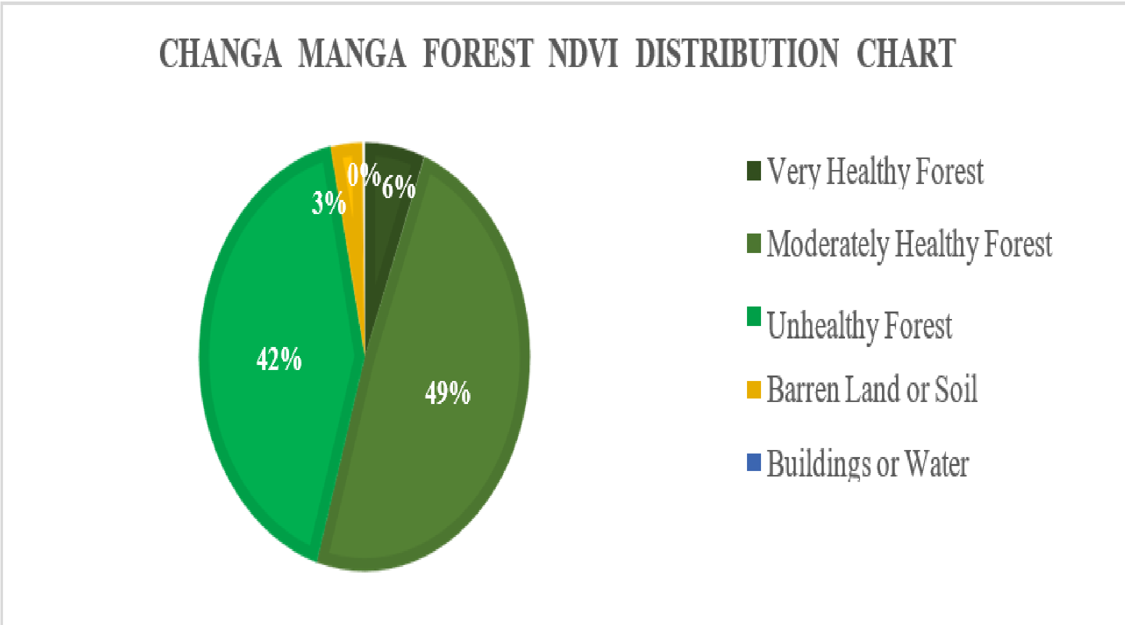

Fig 3.2: Changa Manga Forest NDVI Ranges Distribution Chart

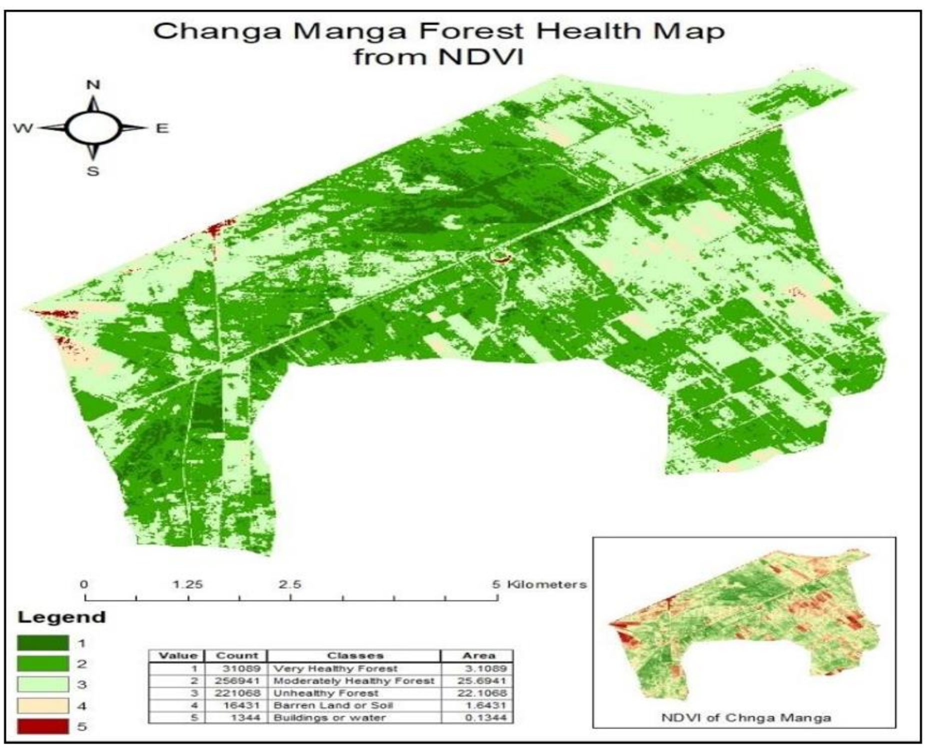

Fig 3.3: Changa Manga Forest Health Map from NDVI of 2018

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3.3 Forest Health Analysis as NDWI

The Normalized Difference Water Index (NDWI) analysis was performed on our imagery of both study areasof the year 2018. After analyzing the healthy and unhealthy forests, we classify the ranges of NDWIshown in **Table 3.3**.

The Normalized Difference Water Index (NDWI) is used to measure the health conditions of Changa Manga Forest, and the map shows those conditions visually. A popular metric for assessing the water content and health of plants is the NDWI. The color system used on the map designates various degrees of forest health: Green: Denotes regions with lush vegetation. Light Green: Denotes forest regions that are reasonably healthy.

Grey: Indicates degraded or unhealthy forest patches. White: Denotes regions devoid of any flora or bodies of water. Forest Health's Spatial Distribution. The Changa Manga Forest's geographical distribution of forest health is clearly shown on the map. It displays regions that have:

Table 3.3: Changa Manga Forest NDWI Ranges with Area Distribution

Value	Features	NDWI Ranges	Area (km^2)	Area (%)
1	Very Healthy Forest	0.2 - 1	3.68	6.98
2	Moderately Healthy Forest	0.15 - 0.25	24.65	46.78
3	Unhealthy Forest	0.05 - 0.15	20.55	38.99
4	No Vegetation	-1 – 0.05	3.82	7.25
Total			52.70	100.00

The total area for Changa Manga Forest is around 52.7km^2 and after analysis of NDWI, the distribution chart (figure 4.5), shows that the very healthy forest ranges 0.2-1 covers 3.68km^2 (7%), moderately healthy forest ranges 0.15-0.25 covers 24.65km^2 (47%), unhealthy forest ranges 0.05-0.15 covers 20.55km^2 (39%), and no vegetation ranges -1-0.05 covers 3.82km^2 (7%) of the whole area respectively. High levels of health and vegetation cover are concentrated areas of the forest, which probably indicates ideal growing circumstances.

In different degrees seen across the forest, moderate vegetation health indicates places that may be under stress or degradation. Grey and white patches indicate places with considerable environmental problems or disruptions, little vegetation cover, or unhealthy conditions.

Further Understanding The map indicates that various sections of the forest have varying levels of health. There seem to be a mix of regions facing deterioration and others with comparatively robust forest health. The health of the surrounding forest may be impacted by the existence of water bodies, which are shown as dark blue.

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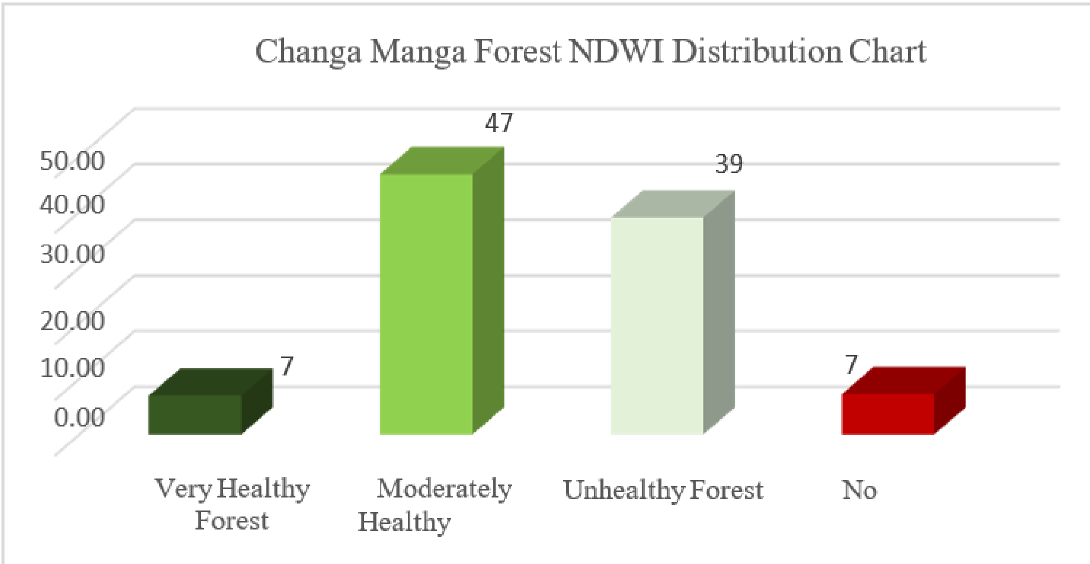

Fig 3.4: Changa Manga Forest NDWI Ranges Distribution Chart

The results were reclassified and generated a forest health map as shown in figure **3.6** below.

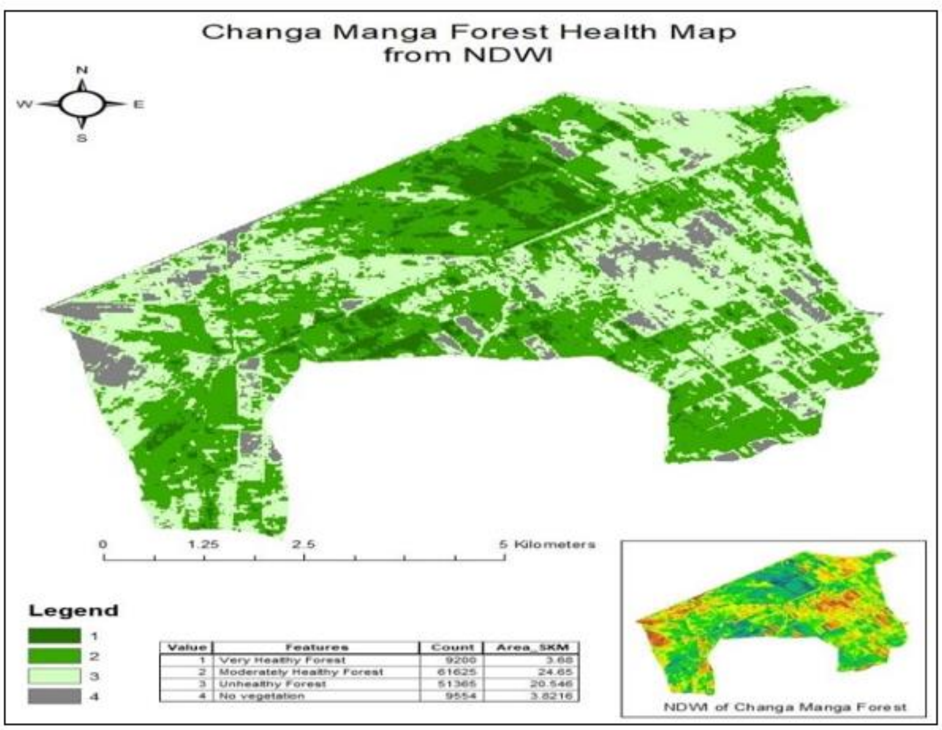

Fig 3.5: Changa Manga Forest Health Map from NDWI of 2018

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3.4 Forest Health Analysis as NDPI

The Normalized Difference Pigment Index (NDPI) analysis was performed on our imagery of both study areasof the year 2018. After analyzing the healthy and unhealthy forests, we classify the ranges of NDPIshown in **Table 3.4.** Using the Normalized Difference Plantation Index, the table presents an overview of Changa Manga Forest's current state of health (NDPI). This indicator is frequently used to assess the vitality and health of forests. Ranges of the NDPI and Forest Health

Five classifications are created from the NDPI values, each of which represents a distinct degree of forest health: Very Healthy Forest (NDPI 0.206-0.337): The healthiest and most vigorously vegetated areas. Forests with moderate levels of health are classified as moderately healthy (NDPI 0.177-0.206). The NDPI 0.151-0.177 designation for moderately unhealthy forests refers to those that exhibit mild stress or deterioration. Extremely Unhealthy Forests (NDPI 0.118-0.151): These are forests that are severely stressed or degraded. Low or no vegetation cover is represented by the NDPI value of -0.131, "No Vegetation."

The area included in each category of forest health is also quantified in the table: 6.66 km² of extremely healthy forest (12.64% of the total area), 15.71 km² of moderately healthy forest, or 29.81% of the total area, 15.86 km² of moderately unhealthy forest (30.10% of the total area), 10.59 km² of extremely unhealthy forest (20.11% of the total area), 3.87 km² (7.34% of the total area) are devoid of vegetation. Overall, Changa Manga Forest's health state is mixed, according to the data. A sizeable chunk (50.21%) is categorized as either moderately unhealthy or extremely unhealthy, whereas a significant amount (42.45%) falls into the moderately healthy and very healthy categories. Moreover, just around 7.34% of the forest is covered in vegetation.

Table 3.4: **Changa Manga Forest NDPI Ranges with Area Distribution**

Value	Features	NDPI Ranges	Area (km^2)	Area (%)
1	Very Healthy Forest	0.206-0.337	6.66	12.64
2	Moderately Healthy Forest	0.177-0.206	15.71	29.81
3	Moderately Unhealthy Forest	0.151-0.177	15.86	30.10
4	Very Unhealthy Forest	0.118-0.151	10.59	20.11
5	No Vegetation	-0.131	3.87	7.34
Total			52.69	100.0

3.4.1 Changa Manga Forest Health Map from NDPI

The results were reclassified and generated a forest health map as shown in figure **3.7** below. The NDPI created for the Changa Manga Forest Health Map, which divides the forest's health into five categories: Very Healthy Forest, Moderately Healthy Forest, Moderately Unhealthy Forest, Very Unhealthy Forest, and No Vegetation. The classification system is based on vegetation cover and health. These classes are distributed spatially throughout the forest region in different proportions, as shown by the map. Green areas showed robust woods, whereas yellow and orange areas show

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different levels of deterioration. Notably, white is used to represent places devoid of flora, possibly indicating deforestation or arid territory. For Changa Manga's conservation and forest management initiatives, this map offers insightful information.

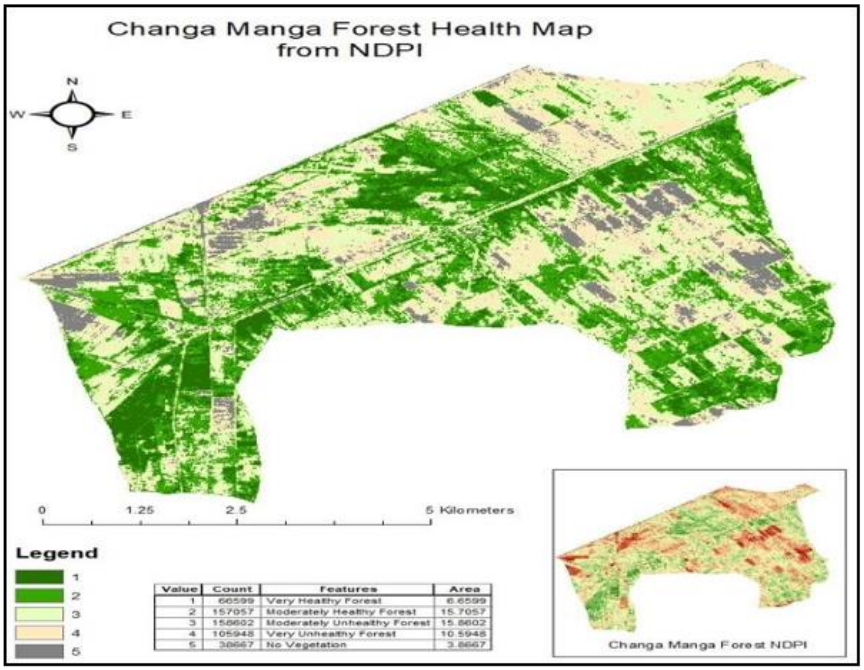

Fig 3.6: Changa Manga Forest Health Map from NDPI of 2018

4. CONCLUSIONS AND RECOMMENDATIONS

The use of Remote Sensing and Geo-Information techniques has been extremely valuable in the identification, monitoring, and mapping of forests in Pakistan. The information result is very important for better planning and management of forests. Overall results of this study show that spectral indices, the reclassification tool of ArcGIS 10.1, and Sentinel-2 Satellite can offer valued data in the assessment of forest health status. The application of Remote Sensing technology can significantly assist not only in monitoring forests but also in the choice of new places for afforestation initiatives to increase the forest cover for a better ecosystem.

Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), and Normalized Difference Pigment Index (NDPI) are highly effective vegetation indexes for evaluating forest health. These indexes used different band combinations and showed that the selection of these has a significant impact on results. After Evaluating NDVI, NDWI, and NDPI, we have an overall 50.3% area of our study area was a healthy forest. Then unhealthy forests cover overall 44.7%.

A forest health map area is made which guides in assessing forest health status. The healthy part of the forest has more greenness value, water contents, and optimum

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chlorophyll pigment contents, which means that it is stress and disease-free and contributes to the ecosystem effectively. However unhealthy partsof the forest may be affected by some diseases, water stress, atmospheric pollution, or improper implicationof forest management strategies.

Data Availability: The data supporting the findings of this study are available from the corresponding authors upon reasonable request.

Conflicts of interest: The authors declare that they have no conflicts of interest.

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References

1) Angela, L., S. Erasmi, D. J. King, P. Magdon and M. Heurich. 2017. Understanding forest health with remote sensing-part II—a review of approaches and data models. Remote Sens., 9:129 1-33

2) Ashok, A., Rani, H. P., & Jayakumar, K. V. (2021). Monitoring of dynamic wetland changes using NDVI and NDWI based landsat imagery. *Remote Sensing Applications: Society and Environment*, *23*, 100547.

3) Bennett, D.D., & Tkacz, B.M. (2008). Forest health monitoring in the United States: a program overview. Australian Forestry, 71, 223 - 228.

4) Bradshaw, C. J. A., Sodhi, N. S., & Brook, B. W. (2009). Tropical turmoil: a biodiversity tragedy in progress. Frontiers in Ecology and the Environment, 7(2), 79-87.

5) Ceccato, P., S. Flasse, and J.M. Gregoire. 2002. Designing a spectral index to estimate vegetation watercontent from remote sensing data: Part 2. Validation and applications. Remote Sens. of Environ., 82: 198-207.

6) Ceccato, P., S. Flasse, S. Tarantola and J.M. Gregoire. 2001. Detecting vegetation water content using reflectance in the optical domain. Remote Sens. of Environ., 77:22–33.

7) Crippen, R.E. 1990. Calculating the vegetation index faster. Remote Sens. of Environ., 34:71-73.

8) Fassnacht, F. E., Latifi, H., Stereńczak, K., Modzelewska, A., Lefsky, M., Waser, L. T., ... & Ghosh, A. (2016). Review of studies on tree species classification from remotely sensed data. Remote Sensing of Environment, 186, 64-87.

9) Gao, B.C. 1995. Normalized difference water index for remote sensing of vegetation liquid water from space. Proceedings of SPIE, 2480:225-236.

10) Gao, Y., C. Chen and J. Hang. 2015.Optical sensing of vegetation water content: a synthesis study. J. Sel. Top. Appl. EARTH Obs. Remote Sens., 8:1–9.

11) Goetz, S. J., Steinberg, D., Dubayah, R., & Blair, J. B. (2015). Laser remote sensing of canopy structure and biophysical properties. Progress in Physical Geography, 29(4), 433-452.

12) Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., ... & Townshend, J. R. (2013). High-resolution global maps of 21st-century forest cover change. Science, 342(6160), 850-853.

13) Hassan, Q., M. Luqman and S. Khan. 2016. A study of forest land cover changes using satellite remote sensing in Thatta district Pakistan. Sci. Int. Lahore. 28:4069-4075.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 09 | 2024
DOI: 10.5281/zenodo.13744041

14) Jiang, Z., J. Chen, Y. Chen, and X. Zhang. 2006. Analysis of NDVI and scaled difference vegetation index retrievals of vegetation fraction. Remote Sens. Environ., 101:366-3.

15) Kolb, T.E., M.R. Wagner and W.W. Covington. 1994. Forest health from different perspectives, Proceedings of the 1995 national sivilculture workshop. Gen. Tech. Rep., 267:5-13

16) Kumari, K., S. Asok, V. A. Ferrer and P. Suresh. 2017. A comparative appraisal on satellite remote sensing data as a utilitarian tool in forest health and fragmentation analysis. Int. J. Innov. Res. in Sci., Engg. & Tech., 6:12184-12194.

17) Lea, H., T. Kazantsev, A. Kuusk and J. Galmés. 2017. Generality of relationships between leaf pigment contents and spectral vegetation indices in Mallorca. Regional Environ., 17:2097.

18) Lechner, A. M., Foody, G. M., & Boyd, D. S. (2016). Applications in remote sensing to forest ecology and management. PeerJ, 4, e1637.

19) Lechner, A. M., Foody, G. M., & Boyd, D. S. (2020). Applications in remote sensing to forest ecology and management. One Earth, 2(5), 405-412.

20) Massey, R., Berner, L. T., Foster, A. C., Goetz, S. J., & Vepakomma, U. (2023). Remote sensing tools for monitoring forests and tracking their dynamics. In Boreal Forests in the Face of Climate Change: Sustainable Management (pp. 637-655). Cham: Springer International Publishing.

21) Mayaux, P., P. Holmgren, F. Achard, H. Eva, H. Stibig and A. Branthomme. 2005. Tropical forest cover change in the 1990s and options for future monitoring. Philosophical Trans. R. Soc., 360:373-384.

22) Myeong, S., Nowak, D. J., & Hopkins, P. F. (2006). Urban cover mapping using digital, high-spatial resolution aerial imagery. Urban Ecosystems, 9(4), 243-260.

23) Nagendra, H., & Ostrom, E. (2012). Polycentric governance of multifunctional forested landscapes. International Journal of the Commons, 6(2), 104-133.

24) Nguyen Trong, H., Nguyen, T. D., & Kappas, M. (2020). Land cover and forest type classification by values of vegetation indices and forest structure of tropical lowland forests in central vietnam. International Journal of Forestry Research, 2020(1), 8896310.

25) O'Laughlin and J. Cook. 2003. Inventory-based Forest health indicators. J. Implic. Natl. For. Manag..101:11–17.

26) Penuelas, J., F. Baret and I. Filella. 1995. Semi-empirical indices to assess carotenoids/chlorophyll ratio from leaf spectral reflectance. Photosynthetica, 31:221-230.

27) Penuelas, J., I. Filella, C. Biel, L. Serrano and R. Save. 1995. The reflectance at the 950-970 region as an indicator of plant water status. Int. J. Remote Sens., 14:887-1905.

28) Pesaresi, M., C. Corbane, A. Julea, A. J. Florczyk, V. Syrris, and P. Soille. 2016. Assessment of the added-value of sentinel-2 for detecting built-up areas. Remote Sens., 8:299.

29) Pullanagari, R. R., G. Kereszturi and I. Yule. 2018. Integrating airborne hyperspectral, topographic, and soil data for estimating pasture quality using recursive feature elimination with random forest regression. Remote Sens., 10:1117.

30) Qin, Q., Xu, D., Hou, L., Shen, B., & Xin, X. (2021). Comparing vegetation indices from Sentinel-2 and Landsat 8 under different vegetation gradients based on a controlled grazing experiment. *Ecological indicators*, *133*, 108363.

31) Richter, R. 2007. Atmospheric / topographic correction for satellite imagery. ATCOR- 2/3 User-Guid, 6.3:1–71.

ISSN: 1673-064X
E-Publication: Online Open Access
Vol: 67 Issue 09 | 2024
DOI: 10.5281/zenodo.13744041

32) Russell, S.J., P. Norvig, J. F. Canny, J. M. Malik, D. D. Edwards, and S. J. S. Jonathan. 1995. A modern approach. Artificial Intelligence. Prentice-Hall, Egnlewood Cliffs, 25:27.

33) Sajid, A., A. Hussain, U. Wahab, S. Ali, Z. Ahmad and A. Ali. 2015. Application of remote sensing and GIS in forest cover change in tehsil Barawal, district Dir, Pakistan. Am. J. Plant Sci., 6:1501- 1508.

34) Shao, Z., J. Deng, L. Wang, Y. Fan and Q. Cheng. 2017. Remote sensing fuzzy auto-encode based clouddetection for remote sensing imagery. Remote Sens., 9:4.

35) Shruti Kanga. 2017. Forest cover and land use mapping using remote sensing and GIS technology. J. Clim. Change & Water, 4:13-17.

36) Solberg, S. 1999. Forest health monitoring: evaluation of methods, trends and causes based on a norwehian nationwide set of monitoring plots. Norwegian Forest research Institute, Oslo.

37) Stone, C., & Coops, N. C. (2020). Assessment and monitoring of forest health using remote sensing. New Zealand Journal of Forestry Science, 50, 1-17.

38) Tortora, C., Miglietta, F., Sabia, S., & De Martino, A. (2011). Remote sensing techniques for natural resource monitoring. Applied Environmental Research, 33(4), 69-80.

39) Turner, W., Spector, S., Gardiner, N., Fladeland, M., Sterling, E., & Steininger, M. (2015). Remote sensing for biodiversity science and conservation. Trends in Ecology & Evolution, 18(6), 306-314.

40) Turner, W., Spector, S., Gardiner, N., Fladeland, M., Sterling, E., & Steininger, M. (2015). Remote sensing for biodiversity science and conservation. Trends in Ecology & Evolution, 18(6), 306-314.

41) Ustin, S. L., A. Gitelson, S. Jacquemoud and P. Zarco-Tejada. 2009. Retrieval of foliar information about plant pigment systems from high resolution spectroscopy. Remote Sens. Environ., 113:67–77.

42) Wang, Z., G. Liu, J. Zhang, Y. Wang and L. Tang. 2012. Temporal and spatial variation in soilorganic carbon sequestration following revegetation in the hill Loess Plateau, China. Catena, 99: 26- 33.

43) William, M.C. 2000. Remote sensing in forest health protection. Forest Services, USDA.

44) Wulder, M. A., White, J. C., Loveland, T. R., Woodcock, C. E., Belward, A. S., Cohen, W. B., ... & Roy, D. P. (2012). The global Landsat archive: Status, consolidation, and direction. Remote Sensing of Environment, 122, 2-10.

45) Wulder, M. A., White, J. C., Loveland, T. R., Woodcock, C. E., Belward, A. S., Cohen, W. B., ... & Roy, D. P. (2012). The global Landsat archive: Status, consolidation, and direction. Remote Sensing of Environment, 122, 2-10.

46) Zhaoqin, L., D. Xu and X. Guo. 2014. Remote sensing of ecosystem health: opportunities, challenges, and future perspectives. Sensors 14:21117-2.