

## MONITORING VEGETATION DENSITY USING SPECTRAL VEGETATION INDICES: A CASE STUDY OF MALAM JABBA REGION, DISTRICT SWAT, PAKISTAN

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### ABSTRACT:

The limited forest resources with a higher deforestation rate per annum, Pakistan ranks the second highest in Asia. FAO reported that the annual forest cover change rate during 1990-2000 was -1.8% and increased to -2.2 % between 2000- 2010. Most of Pakistan's total forest resources, dominantly natural forest, are situated in the Northern regions. Stepping into the corridor of the 21st century, the Spatio-temporal analysis has been evolved using Satellite Remote Sensing data aided with Geographic Information System (GIS) platforms. The study is carried out over the mountainous vegetation land of Malam Jabba, district Swat, Khyber Pakhtunkhwa, Pakistan. Due to varying topography and the region being part of the agro-forestry zone, drastic changes were observed in vegetation and built-up areas. The vegetation cover has been identified and classified based on elevation throughout the area. This study has provided essential insights into vegetation cover change over a period of four decades. Vegetation cover is classified into high to very high, medium, and low to very low. The Landsat and the SRTM DEM satellite imageries were exported to the ERDAS software for pre-and post-processing, and for further analysis ArcGIS 10.5 was used, where the vegetation density change for each period was computed from the pixels by using vegetation indices like VCI, NDVI, and SAVI. The results show a significant decline from 1980 to 2010 in vegetation density in the Northwestern direction; however, an increasing trend can be seen in 2020 due to awareness and the Government's Billion Tree Tsunami initiative. Such studies can significantly benefit researchers and decision-makers interested in satellite remote sensing for forest and other vegetation cover monitoring and management at a regional scale.

### 1. INTRODUCTION AND BACKGROUND

Vegetation plays a critical role in regulating the Earth's surface temperature and precipitation, preserving soil nutrients, minimizing flooding, and fixing carbon (Andrade, E. M. et al., 2020). It also provides important ecosystem services to people such as air purification, erosion control, and biological reservoirs (Cudlín, P. et al., 2013). Deforestation is the second-largest global concern due to anthropogenic carbon dioxide emissions and is likely responsible for 10-25% of carbon dioxide emissions worldwide (Deka, J. et al., 2013). The changing climate has impacted the overall vegetation patterns and the situation is expected to prevail if not addressed (Khosravi, H. et al., 2017),

Studies and research on vegetation dynamics are at the upfront globally to address climate change (Wu, D.H. et al., 2015) The evaluation and interpretation of vegetation dynamics and its increasing trends due to climatic and environmental conditions, including temperature, rainfall, topography, land, and soils, play a significant role in better understanding the vegetation stress and its related effects (Djebou, et al., 2015). Changes in vegetation cover and biomass may lead to changes in the complex earth-atmosphere processes and climate dynamics. (Friend, A.D, et al., 2014; Zhang, Y. et al., 2016).

Vegetation mapping also indicates valuable information for understanding and interpreting the natural and anthropogenic change in the environments through quantifying vegetation cover from local to worldwide scales at a specific time or over a continuous period. It is vital to obtain the current condition of vegetation cover in order to initiate vegetation restoration and protection programs. (Yichun Xie, et al. 2008).

Because of constrained forest resources with a deforestation rate of 4.6% for each annum, Pakistan places the second highest in the world and causes over-exploitation of forest resources nationally (Qasim et al., 2011; Shehzad, K. et al., 2014).

Earth Observation satellite images are beneficial for visualizing natural resources and land cover change dynamics in both spatial and temporal dimensions. Temporal analysis of remotely sensed data together with GIS has evolved as a valuable set of techniques to assess pressure exerted on the ecosystem, forest cover change detection, and modeling that is very useful for effective management and planning ((Georg Bareth, et al. 2018 ; Reddy, 2013).

The Landsat program revolutionized the moderate-resolution Earth remote sensing in the 1970s. With eight successful and ninth ongoing missions over more than 50 years, Landsat has documented and recorded the digital earth on a continuous interval with spectral, spatial, radiometric, and geometric performance, as well as a data acquisition strategy, availability, and products with the incremental improvements (Roy et al., 2014; Wulder et al., 2016).

Much of the earth's surfaces comprises vegetation cover, and the vegetation indices are one of the valuable indicators for the assessment of global vegetation cover and are also used to indicate the amount of green vegetation. Normalized Difference Vegetation Index (NDVI) is used to analyze vegetation cover. NDVI was introduced by Rouse *et al.* (1974) in order to produce separate green vegetation from its background soil brightness using Landsat MSS digital data. There are many applications of NDVI, such as agricultural production, desertification, forest fire, vegetation assessment and vegetation health monitoring (Jeevalakshmi et al., 2016; Kong et al., 2016).

The Soil-Adjusted Vegetation Index (SAVI) was proposed by Huete (1988) to compensate sensitivity to bare soil. Kogan (1995) proposed a Vegetation Condition Proportion (VCP) that utilized historical maximum and minimum NDVI data to measure vegetation conditions against the historical worst situation. The VCP has been successfully used for drought monitoring. The relative measurement of the current vegetation condition against a reference condition is critical for understanding, interpreting, and quantifying vegetation condition reality.

In this study, the normalized difference vegetation index, soil Adjusted vegetation index, and vegetation cover proportional (NDVI, SAVI, and VCP) are used to understand and assess vegetation cover throughout the study area, which is significant for enhancing the accuracy of vegetation cover classification change. Vegetation cover together with the indices and elevation data is classified into high to very high, medium, and low to very low.

## 2. MATERIALS AND METHOD

### 2.1 Study Area

The study was carried out in Malam Jabba region, district Swat, Khyber Pakhtunkhwa, Pakistan. Geographically, it stretches between 34° 47' 57" North latitude and 72° 34' 19" East longitude with an elevation range between 2000-3000 m above sea level. Malam Jabba is a well-forested and agro-ecological zone and has a varying topography with a well-known hill station in the Hindu Kush Mountain. The main vegetation covers are represented by crop growing and forest, especially pine forest. Agricultural activities are more predominant in past decades due to deforestation.

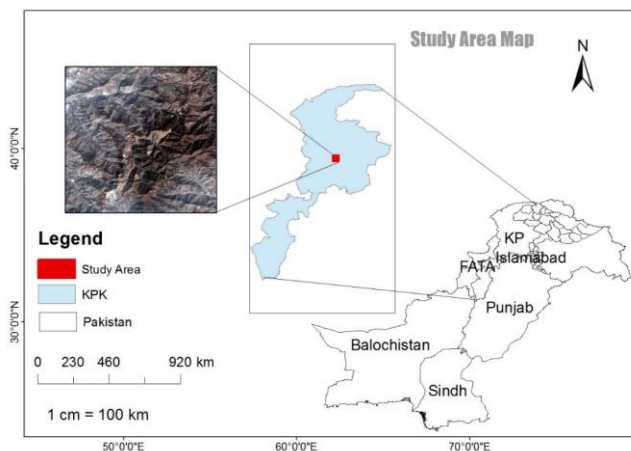


Figure 1: Study Area Map

### 2.2 DATA ACQUISITION

The satellite data was acquired for the month of July due to the least cloud and snow cover in the Malam Jabba region of

Khyber Pakhtunkhwa, Pakistan. The entire archive was observed and examined carefully to observe the images taken throughout July. For the Spatio-temporal analysis, remotely sensed data for forest cover assessment were obtained for three years, covering four decades 1980, 2000, and 2020. The data were obtained from the United States Geological Survey (USGS) consisting of Landsat MMS with a spatial resolution of 60m having four bands. Landsat ETM+ having a spatial resolution of 30m consists of 8 bands. The spatial resolution of Landsat OLI is 30m. The Digital Elevation Model (DEM) was acquired from the Shuttle Radar Topography Mission (SRTM) of the United State Geological Survey (USGS). The details of the datasets and software used for analysis are shown in table 1.

SR.no	Data type	Spatial Resolution	Time period	Purpose
1	Landsat 1(MSS)	60m	1980	Vegetation change detection
2	Landsat 7(ETM+)	30m	2000	
3	Landsat 8(OLI)	30m	2020	
4	DEM(SRTM)	30m		Topographic Normalization
5	ENVI	Image processing, analysis, and mapping		
6	ArcGIS 10.5			

Table 1: Datasets and Processing Tools Used

### 2.3 Data Processing

The spatial resolution of the Landsat satellite data offers reliable, relatively consistent, and proper resolve information that is important for the assessment of vegetation cover changes that occur with time. Different corrections should be done to remotely sensed data after the data acquisition process because it can reduce the efficiency of obtaining information and the quality of satellite images. Consequently, it is essential to pre-and post-process the satellite data before proceeding to actual interpretation and analysis.

The satellite imageries of Landsat and DEM were imported to the ENVI software and used for pre and post-processing such as layer stacking, clipping, atmospheric and topographic correction of satellite imageries, and ArcGIS 10.5 for further analysis, where the vegetation cover change for each period was computed from the pixels. The study area is covered in a single scene therefore no mosaicking was needed. The layer stacking of different bands of Landsat (MSS, ETM+, OLI) images of 1980, 2000, and 2020 respectively;u. The working methodology included in the study can be seen in the figure below. DEM stores information on continuously varying variables like elevation, ground depth, water depth, etc. DEM (SRTM) was obtained from USGS for the study area of 30m.

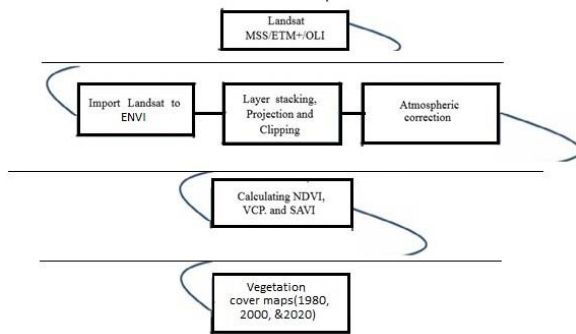


Figure 2: Working Methodology

## 2.4 Vegetation Index Computation

The green color in vegetation is due to the amount of chlorophyll present in leaves. The spectral response of chlorophyll towards the electromagnetic spectrum is its reflectance and is strong and maximum in the near-infrared region while reflection is weak and minimum in the red portion of the electromagnetic spectrum, due to absorption by chlorophyll. In this study, different types of indices were used in order to estimate the vegetation cover. The following indices were used to assort vegetation into high to very high, medium, and low to very low classes.

### 2.4.1 Normalized Difference Vegetation Index (NDVI)

NDVI is expressed as the difference between the near-infrared and red bands normalized by the sum of those bands. Additionally, ranging from -1 to 1, with 0 representing the approximate value of no vegetation, and negative indicating non-vegetated surfaces. The highest value of the NDVI indicates forest and the lowest value indicates no or less vegetation. Thus, NDVI above 0.51 is considered high to very high vegetation cover. The NDVI is calculated as,

$$NDVI = (NIR - RED) / (NIR + RED). \quad (1)$$

NIR and RED are the reflectance value of the near-infrared and red bands.

### 2.4.2 The Soil-Adjusted Vegetation Index (SAVI)

It is intended to reduce the effects of soil background on the vegetation signal by incorporating a constant soil adjustment factor L into the denominator of the NDVI equation that varies with the reflectance characteristics of the soil. The L factor chosen depends on the density of the vegetation. In cases of very low vegetation, the use of an L factor of 1.0 is suggested, for intermediate 0.5, and for high densities of 0.25. For this study, the value of 0.5 is selected for the high density of vegetation. Thus, we applied 0.5 as a constant factor (L). SAVI is calculated as

$$SAVI = (NIR - RED) * 1 + L / (NIR + 1 + L) \quad (2)$$

Where NIR is the near-infrared band, red refers to the red band, and L is the constant factor.

### 2.4.3 Vegetation Cover Proportion (VCP)

The Vegetation Cover Proportion VCP explains the density of vegetation cover based on the stems, branches, and leaves of the vegetation. The VCP depends on the NDVI maximum and minimum, and the maximum and minimum NDVI represents vegetation NDVI and Smooth NDVI. The value falls between 0 and 1. In this study, the VCP is adopted to indicate the highest, medium, and lowest vegetation cover throughout the study periods. VCP can better indicate stress on vegetation than NDVI. The assumption of VCP for monitoring vegetation dynamics is affected by the variation and change in current climatic conditions. In a certain climate season and region, an extreme drought will weaken vegetation growth and lead to the lowest NDVI in the multiyear observations. VCP is a better indicator of drought stress on vegetation than NDVI. In this study, a VCP >0.70 is considered high to very high vegetation cover. The VCP is given by the following formula:

$$VCP = (NDVI - NDVI_{min}) / (NDVI_{max} - NDVI_{min}) \quad (3)$$

Where  $NDVI_{max}$  and  $NDVI_{min}$  represent the maximum and minimum values of NDVI.

## 3. RESULT AND DISCUSSION

By use of the vegetation indices NDVI, SAVI, and VCP, the study area was classified into low to very low, medium, and high to very high vegetation density. These vegetation indices are widely used for various applications. They provide an absolute measurement of the vegetation condition. However, they do not provide a relative measurement against a given reference condition, such as the historical average condition or the historical worst condition or last year's condition, etc. Kogan, 1995 proposed a vegetation cover proportion (VCP) that utilized historical maximum and minimum NDVI data to measure vegetation conditions against the historical worst situation. This VCI has been successfully used for drought monitoring (Z. Yang 2011).

This study uses VCP for the monitoring and evaluation of vegetation density cover in the study area for the 1980s, 2000s, and 2020s. Three classes including low – very-low, medium, and high – very-high vegetation cover were classified for each 1980, 2000, and 2020 Landsat satellite imagery using VCP. The result demonstrated and shown that the vegetation density cover declined from 1980 to 2020. While there is an increase in other land covers from 1980 to 2020, the total area of the study area is comprised of 341.08 km<sup>2</sup>. The overall DEM, low – very-low, medium, and high – very-high vegetation cover was, respectively, located below 1200 m, between 1200 and 1800 m, and above 1800 m. The values of vegetation indices for high to very high, medium, and low to very low vegetation cover and its distribution with elevation are shown in table .2.

Vegetation cover	DEM	NDVI	VCI	SAVI
high-very high	>1800	>0.5	>0.70	>0.43
Medium	1200-1800	0.3-0.5	0.54-0.70	0.23-0.43
low-very low	900-1200	<0.20	<0.54	<0.23

Table 2: Summary of the values of vegetation indexes for high to very high, medium, and low to very low vegetation cover and its distribution with elevation.

Vegetation cover	DEM	VCP	1980 (%)	2000 (%)	2020 (%)
high-very high	>1800	>0.70	41.5	23.3	26.1
medium	1200-1800	0.54-0.70	20.4	24.5	17.7
low-very low	900-1200	<0.54	38.1	52.2	56.2

Table 3: Summary of the values of VCI for high to very high, medium, and low to very low vegetation cover and its distribution with elevation from 1980 to 2020.

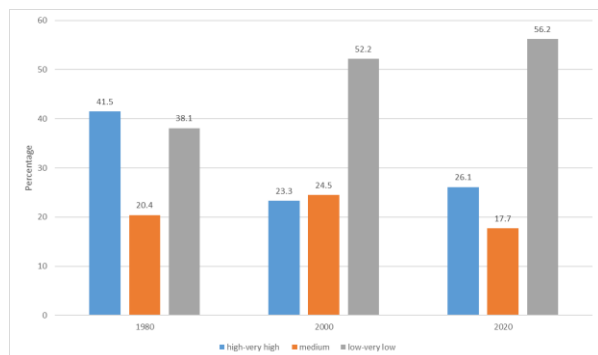


Figure 4: Shows the statistics of total vegetation density change from very high to very lower in the 1980s, the 2000s, and 2020

The result in Fig. 4.1 and Table4.1 that very high vegetation density occupied the largest percentage of the area having an altitude greater than 1800m, with a very high vegetation density of approximately 41.5%, 23. %, and 26.6 % of the total area from 1980, 2000, and 2020 respectively. Medium vegetation density located mostly from 1200m -1800m altitude in a large portion of the approximately 20.46%, 24.5%and 17.57% from 1980 and 2020. While most of the low to very low vegetation density comprises a height of less than 1200m. low to very low vegetation density was estimated at 38.1% and 56.2%, respectively, in 1980 and 2020. The result (Table 4.1) revealed that the very high vegetation density cover was reduced by up to 15% throughout the study period in the past four decades. While the increase in very low to low vegetation density from the 1980s to 2020 was found of 19% of the increase in the total area.

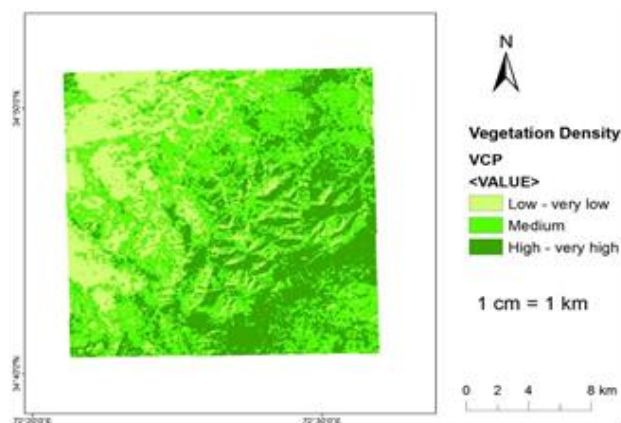


Figure 5: Distribution of vegetation cover based on VCP in the 2000s

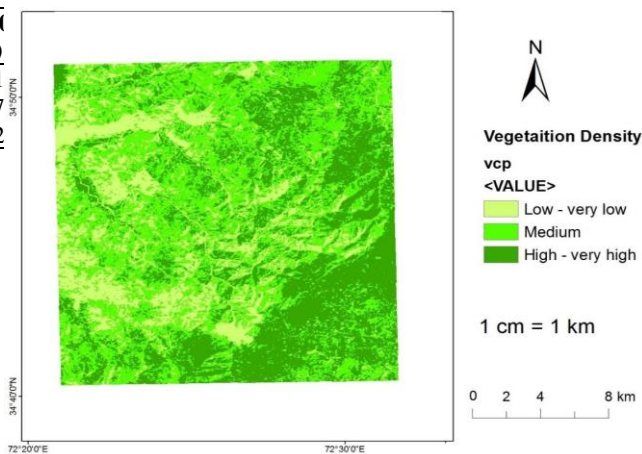


Figure 6: Distribution of vegetation cover based on VCP in the 1980s

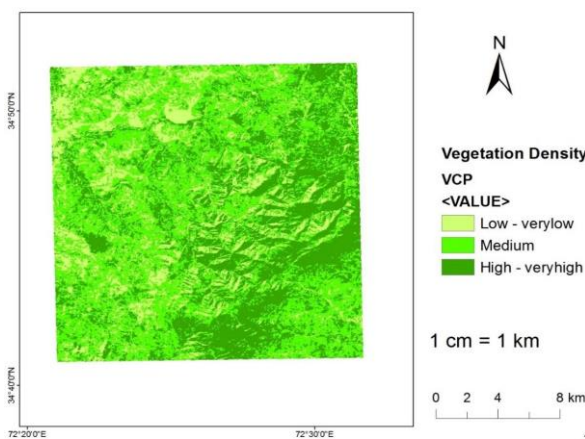


Figure 7: Distribution of vegetation cover based on VCP in the 2020s

Figures 5, 6, and 7 show the results of vegetation density maps. It was found that in the 1980s, vegetation density was maximum in the direction of the east, northeast, southeast, and some parts of the southwest in the Malam Jabba region. However, medium vegetation density is located mainly from 1200m -1800m altitude in a large portion of the southwestern region and center of the study area. Low vegetation density cover was observed in the western and southern parts of the region with lower elevations. Figure 6 shows that in the 2000s, low vegetation density cover was observed in the western and southern parts of the region with lower elevations. vegetation density was maximum in the direction of the east, southeast, and some parts of the southwest in the Malam Jabba region. However, increases were observed in medium vegetation density in a large region of the northern-western region and center of the study area.

Generally, forest loss was very significant throughout the study period from the early 1970s to the end of 2010. In the study area, deforestation is commonly caused by anthropogenic factors, population growth, and urbanization, and the cutting of trees or forests for different purposes, including traditional farming practices, timber, fuelwood, particularly from 2000 to 2010s, population growth and urbanization, among numerous hot spots of deforestation throughout the world, Pakistan is the second maximum deforestation level in Asia. Pakistan because of constrained forest resources with a deforestation rate of 4.6% for each annum, places the second highest in the world and



causes overexploitation of forest resources nationally (Qamer et al., 2012).

In this study, we have extracted and quantified the historical vegetation cover change for the 1980s, 2000s, and 2020 from Landsat MSS and ETM+, and OLI. The Landsat satellite images used in this study have 30m spatial resolution, which is relatively low for use in detailed land use and land cover classification (Iqbal and Khan, 2014). In addition, the accuracy may be affected by the shadows produced by mountain slopes, on the Southeastern escarpment of the study area, where the landscape is highly rugged and mountainous topography.

#### 4. CONCLUSION AND RECOMMENDATION

This research uses the spectral vegetation indices approach to extract and analyze the vegetation density in Malam Jabba, district Swat, Khyber Pakhtunkhwa based on the time series Landsat data and Digital Elevation Model (DEM). The study demonstrated that vegetation loss is a severe environmental concern in the country, where approximately 15% of the total higher vegetation density has been lost in the past 40 years. Anthropogenic and natural activities are the main factors of deforestation in the country, such as cultivation, gathering fire, woodcutting, urbanization, road construction, and overgrazing. Deforestation was a serious environmental problem in all regions of the country. Vegetation density maps having three classes (high to very high, medium, low to very low) estimated for 1980, 2000, and 2020 show that significant decreases were observed between 1980 and 2000 in vegetation density in the Northwestern direction. The government's, 1 billion trees tsunami initiative for afforestation has been first adopted by Khyber Pakhtunkhwa in 2014, and the results show an increase in vegetation density from 2000-to 2020. If proper management, planning, and strategies are not implemented to improve and maintain the existing rate of decline in vegetation density as results negative sequence and impact on the socio and economic situation of the region. This study may be useful as input data for further studies at local, regional, or global scales.

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