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AVIRIS-NG Hyperspectral and Field Spectroscopy Data are Used to Map Vegetation Health Conditions and Assess the Environmental Impact of Coal Mining Sites

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Abstract

Using high-resolution airborne hyperspectral AVIRIS-NG imagery and validated field spectroscopy-based vegetation spectral data, this paper focuses on VHC assessment and mapping. For the purpose of a fine-grained geo-environmental impact assessment, it also quantified the impact of mining on vegetation health. For VHC assessment and mapping in coal mining sites, we have developed and modified vegetation indices (VIs)-based models in this study. In order to identify suitable VIs, we used thirty narrow-banded VIs based on statistical measurement. For the VIs combined pixels analysis, the indices with the highest Pearson's r, R2, and lowest RMSE, as well as the P values, were used. The most elevated unique (Sound versus undesirable) vegetation blend record (VCI) has been chosen for VHC evaluation and planning. The ENVI (software) forest health tool and Spectral-based SAM classification results have also been contrasted with VIs model-based VHC results. The largest difference between the other VCI and the first VCI result was 72.07 percent. The results of the VHC showed that healthy vegetation classes are farther away from mine sites than unhealthy vegetation classes are. It is likewise seen that there is an exceptionally critical positive relationship (R2 =0.70) between VHC classes and distance from mines. The geo-environmental impact assessment of coal mining sites will be guided by these findings.

MiSeq high-throughput sequencing technology was used to examine the changes in soil microbial community diversity and its influence on environmental factors following five years of restoration in an alpine mining area using various soil overburden thicknesses in this study. The findings demonstrated that, under various soil overburden thicknesses, vegetation restoration clearly altered the species composition of soil microorganisms at the OTU (Operational Taxonomic Unit) level. Additionally, the OTU species of soil fungi and bacteria significantly changed in the 15 cm soil overburden thickness. In all three soil overburden thicknesses, the bacterial diversity index was higher than the fungal diversity index, and the microbial diversity index was significantly higher than the bacterial diversity index without the soil overburden thickness (P 0.05). Soil fungi and bacteria shared nearly identical genera and phyla. The microbes were Proteobacteria, Pseudoarthrobacter, and Sphinomonas, and the growths were Ascomycota and Tricharina. The soil overburden thickness affected the relative abundance of soil bacteria and fungi. Vegetation level, inclusion, greenery inclusion, soil temperature, dampness, natural matter, nitrogen content, pH, and soil overburden thickness were the key variables influencing the dirt microbial local area structure. In alpine mining areas, the ideal soil reconstruction measure was a soil overburden thickness of 10 cm. During the rebuilding time of the coal gangue hill in the snow capped locale, critical improvement was seen in the responsiveness of soil microorganisms to thickness throughout the span of five years. In any case, to work with the persistent rebuilding of microorganisms, it is prescribed to carry out measures like covering the region with non-woven textures and changing the pH of the dirt to make better circumstances for microbial development.

Keywords: Spectroscopic remote sensing; Assessment of health conditions; Mining impact on vegetation; Ecological effect evaluation

Introduction

Due to mining activities in India, healthy vegetation and environmental degradation have become serious global issues. Coal mining assumes a fundamental part in financial, yet it likewise hurts plants, the climate, and human existence. The degradation of vegetation has become a serious issue over the past few decades as a result of ongoing climate change and an increase in human-caused activities. In the future, this may pose a greater threat to plant communities and the environment [1]. The contamination of the underlying soil and groundwater, as well as the threat to local plant communities, brought about by opencast and underground mining severely disturb the ground land. The conservation of vegetation cover, plant biodiversity, ecosystem, and land-use system are all harmed by the increase in illegal mining without environmental monitoring. It likewise diminishes the shelter thickness of plants. Dust from mining and transporting minerals has a negative impact on leaves' photosynthetic process. Additionally, it puts plants at mine sites under stress caused by heavy metals, which has a negative impact on their health. Opencast mining is a type of strip mining in which coal is transported and dust settles on trees. It is made low fixation resilience of trees, lessens development levels, and thus, plants may ultimately bite the dust [2]. The richness of species and plant stress are both impacted by higher levels of pollution from coal mining areas. It is additionally impacted herbaceous plant species. Consequently, the loss of sensitive species may result in a decline in the plant community.

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It is now feasible to collect spatial and spectral-based information on the health of vegetation over time using satellite-based technology. For VHC analysis, the majority of researchers used Landsat series data (MSS, TM, ETM+, and OLI). For the purpose of evaluating the vegetation health index (VHI), they used various vegetation indices derived from this data. Those lists are Standardized contrast vegetation file (NDVI), Vegetation greenness record (VGI), Vegetation Division file (VFI), Improved vegetation file (EVI), and so on. A few creators checked vegetation development conditions (VGC) utilizing multispectral remote detecting information in mining destinations. For a considerable amount of time, they used stress, LAI, and greenness indices for VGC analysis. They demonstrated that open-cast mining had gradually reduced the VGC over time. For the purpose of monitoring the vegetation in the mines that surround the sites, some authors utilized very high-resolution multispectral imagery (Worldview-2 or IKONOS). For the purpose of monitoring the health and growth of the vegetation, they utilized a variety of vegetation indicators, such as the NDVI, the green/red ratio, and the Ratio vegetation index (RVI), and they displayed the locations of damage to the vegetation. For vegetation or forest health studies, multispectral satellite image-based VIs were utilized in numerous studies with integrated multi-criteria analysis [3]. They utilized various sorts of factual models like logical ordered progression process (AHP), recurrence proportion (FR), and irregular woods (RF) for timberland wellbeing status and recognized the exceptionally high-risk woodland compartment regions. The powerful vegetation changes and natural medical issue had been observed by certain specialists utilizing Landsat time-series information of mining-impacted regions [4]. They tested various VIs for VHC and environmental stress (ES) analysis, and they found that ES and distance from mines had a clear negative relationship.

The health of the vegetation in our study area is being threatened by an increase in mining and other human-caused activities within and near the lands. Be that as it may, such changes are not yet all around measured at an exceptionally fine-scale level, and their general effects on the fate of the backwoods or vegetation, mining, climate, economies, and human culture are as yet not characterized. The primary objective is to ascertain how mining affects the health of vegetation in terms of spectral and spatial response. Specific objectives include: to validate the airborne hyperspectral AVIRIS-NG data used to assess the health of the vegetation with field leaf spectral data [5]. To dissect consolidated pixels to foster a VIs-based model for better VHC evaluation. To analyze and approve VHC results in view of the VIs model, ENVI FHT, and Unearthly arrangement. to establish a connection between model-based VHC results and NIR reflectance spectra measured in the field. To measure the impact of digging on vegetation wellbeing for natural effect appraisal. to determine a correlation between VHC classes and average distances from mines [6].

Methods and Materials

Concentrate on region: The Jharia Coalfield (JCF) is one of the most extravagant coal saves in India. It is in India's Jharkhand in the South Dhanbad district. Additionally, it is known as India's largest surface coal fire field. It was larger than 450 sq. km in size and was located between 86°06 and 86°27′ E longitude and 23°43–23°45′ N latitude. This region is arranged in a tropical district. In the summer, it can reach 44 °C, while in the winter, it can drop as low as 8 °C [7]. The yearly precipitation differs from 1150 to 1390 mm in the blustery season. Since January 1972, Bharat Coking Coal Limited (BCCL) has operated this colliery. From west to east and 21 kilometers from north to south, the coalfield is approximately 36 km long. Right now, this organization works 36 coal mineshafts, including 11 underground, 16 opencast, and 0 blended mines (Coal India report, on 01.04.2020). This organization likewise runs eight coal washeries, and four are under development around here. The terrain in this region is nearly level, but it slopes toward the Damodar River. There are four major geological or sedimentary formations in this coalfield. The coal crease thickness depends on 4.8 m for one-lift and 12 m for multi-lift. The majority of the study area has been occupied by barren lands as a result of mining activities, and the average depth of underground mining is 250 meters [8]. The majority of the local population works in this coalfield, and residential areas are located close to mine sites. This coalfield is home to fifty-eight villages and half a million people. The JCF is connected to the eastern and south-eastern railway, two national highways. Gardens have taken over the majority of agricultural, park, vegetation, and reclamation lands. However, coal mining caused a number of environmental problems in this area, including acid drainage, ground subsidence, degradation of vegetation, and coal fire (CMFRI and BCCL reports).

Sources of all data and preliminary processing: Airborne hyperspectral Stage 2A satellite information (AVIRIS-NG) have been gathered from the SAC's (Space applications focus, ISRO) Vedas site for VHC concentrate on in mining locales. The site ID for this data acquisition is 212, and it was completed. The AVIRIS-NG data have an estimated 600 cross-track elements and a wavelength range of 380–2510 nm, with a spatial resolution of 4–6 m (avirisng.jpl.nasa.gov) [9]. Due to its higher spectral and spatial resolution, AVIRIS-NG data are better able than other hyperspectral data to identify vegetation features at the narrow level. For a vegetation health assessment, it also offers high accuracy and extensive spectral coverage (425 wavebands). The specifics of the AVIRIS-NG data are shown in Sub.2. Likewise, a field spectroscopy instrument (NIR spectrometer) gathered vegetation spectra information for ghastly examination of vegetation wellbeing. The Stellar-net.us company in the United States developed this instrument. It is estimated at 200-1150 nm frequency with 0.5 nm examining. The field spectrometer's specifics are shown in Sub.3 [10]. For the purpose of spectral-based classification and validation, various VHC locations (latitude and longitude) point data were recorded by a high-accuracy GPS (Garmin Company). Mines overview information, plan, and high-goal Google Earth symbolism were utilized for mines-based VHC investigation, connection, covering, and avocation of VHC results.

Field vegetation wellbeing spectra handling and investigation: Utilizing a field spectroscopy instrument and its extras, we gathered sixteen vegetation reflectance spectra of various medical issue in mining locales. We gathered field vegetation spectra. We kept away from vegetation shelter spectra during ghastly information assortment time. White reference spectra were measured using a standard white panel. The reflectance probe distance (0–3/4 in.), the fiber optic light guideline (FOV-180°), and and the probe angle for measuring leaf reflectance during the field survey (45, 90, and 180 degrees). Water absorption correction, spectral smoothing, and other procedures are included in the pre-processing of raw spectra. During data collection, water absorption errors are caused by components of the atmosphere, and the instrument automatically generates some noises. Based on a literature review, we used Spectra-Wiz software and the Savitzky-Golay algorithm to smooth spectra and remove water absorption and noise bands from wavebands [11]. Then, at that point, we determined the mean spectra of various medical issue of vegetation and imported mean spectra in library manufacturer (ENVI programming) to fabricate an otherworldly library of VHC. In mining sites, this developed library has been utilized for VHC assessment and mapping.

Analysis and pre-processing of hyperspectral data from AVIRIS-NG: There are three types of data products offered by AVIRIS-NG. Level-2 contains atmospherically corrected surface reflectance data, while level-0 contains raw, calibrated radiance. NASA's Jet Propulsion Laboratory (JPL) had already pre-processed the level-2 data (geometric and atmospheric correction). Therefore, after updating the rotation and masking of vegetation pixels using the EVNI software, we directly used this level-2 data to retrieve bands and calculate vegetation indices. Additionally, these data were utilized for VHC classification, matching with field spectra, and the collection of vegetation end member spectra [12]. The ENVI software's minimum noise fraction (MMF) tool used this satellite data to remove noise. Algorithms for the pixel purity index (PPI) were used to apply MMF-corrected data. The ENVI N-dimensional visualizer tool used the PPI image to collect healthy and unhealthy vegetation spectra. The ENVI spectral resampling tool combined image spectra with field spectra. Additionally, a spectral analysis tool was utilized for matching score or similarities analysis between image and field spectra. Absorption spectra matching or similarity score analysis has been carried out with the help of SAM, spectral feature fitting (SFF), and binary encoding (BE) techniques [13-16]. At long last, we have involved SAM calculations for the characterization of VHC in light of these matching spectra.

Conclusion

AVIRIS-NG hyperspectral and field vegetation spectral data-based development of a new method for more accurate assessment and monitoring of VHC at the fine-scale is the primary focus of this study. VHC results have been contrasted and the changed VIs model (0.79), ENVI FHT (0.68), and Ghastly based order (0.74) strategies and showed that the altered VIs model is a superior fit for VHC evaluation in mines destinations. These VHC results would be useful for ecological effect appraisal in mine locales later on. These model-based VHC results demonstrated that healthy vegetation classes are far from mine areas, while unhealthy vegetation classes are found in the mine's buffer sites. This indicates that the mine's anthropogenic activities are destroying the vegetation in the area around the mine. It likewise showed a positive relationship (R2 =0.62 and RMSE=0.31) between models-based VHC results and field-based NIR reflectance spectra of vegetation. The study also reveals a significant positive relationship (R2 =070) between the average distance from mine and VHC classes. This indicates that VHC and environmental stress will be affected in the event of future mining expansion. Notwithstanding, this philosophy would be useful to other mining-impacted vegetation or backwoods regions.

Mechanisms of fault reactivation and its induced coal burst were proposed and then validated by the results of experimental investigations, numerical modeling, and in situ microseismic monitoring. These findings were based on investigations on the relationships between underground coal mining layouts and fault occurrences. Likewise, observing techniques and avoidance systems for shortcoming initiated coal blasts were talked about and suggested.

There were two proposed types of fault reactivations: FRMSS and FRSDS. The cohesion, friction angle, and dip angle of the fault plane, in addition to the minimum principal stress and pore pressure, are the primary factors that influence fault reactivation. The core of the FRMSS mechanism is, in particular, the redistribution of mining-induced stress that occurs when vertical stress increases and horizontal stress decreases, resulting in a decrease in the lateral stress coefficient. The core of the FRSDS mechanism is the seismic-based dynamic loading that causes an ultra-low friction phenomenon to form in the fault plane.

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Conflict of Interest

None

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