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SPECTRAL CHARACTERIZATION AND REMOTE SENSING BASED DETECTION OF COCONUT ROOT WILT DISEASE IN TAMIL NADU: A CASE STUDY

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ABSTRACT

This study investigates the use of remote sensing techniques to analyze the spectral characteristics of healthy and diseased coconut plantations in Kuzhithurai area, Vilavancode Taluk (Kanniyakumari District) and Gudalur Block, Uthamapalayam Taluk (Theni District). Sentinel-2, a satellite imagery was used to collect data on the reflectance patterns of both healthy and diseased coconut trees, with the objective of identifying spectral signatures that differentiate between the two conditions. Results demonstrate that healthy coconut plantations exhibit the characteristic of high reflectance in the near-infrared region (0.7–1.2 µm), indicating healthy plant tissues, while diseased trees show significantly reduced reflectance, particularly in the near-infrared range, due to structural damage and physiological stress from root wilt disease. The study indicated four sample locations with the coconut palms. The study highlights the potential of remote sensing for early detection and spatial mapping of root wilt disease providing a non-invasive, efficient method for monitoring large-scale coconut plantations.

Keywords: Agricultural sustainability, disease detection, non-invasive monitoring, spectral analysis, Sentinel-2A.

INTRODUCTION

Coconut (*Cocos nucifera* L.) is a vital crop in tropical and subtropical regions, significantly contributing to agricultural livelihoods, food security, and economic stability Root wilt disease, caused by the phytopathogen *Ralstonia solanacearum*, is characterized by progressive wilting, yellowing of leaves, and eventual decay of the coconut palm (Singh and Pankaj, 2021; Thirumaran, *et.*

al., 2021). Traditional methods for detecting and monitoring root wilt disease, such as visual inspection of symptomatic trees, are labour-intensive and time-consuming, particularly across large plantations (Suresh, *et. al.,* 2018; Rahman, *et. al.,* 2019; Gonzalez, *et. al.,* 2020). By measuring the reflectance of electromagnetic radiation at various wavelengths, remote sensing captures unique spectral signatures indicative of plant health, including responses to biotic stresses like diseases (Raju *et al.,* 2019; Jayasankar *et al.,* 2021). These changes, influenced by disease progression (Zhang *et al.,* 2018; Chandran *et al.,* 2020), can be detected before affecting the yield. In Vilavancode and Gudalur, root wilt disease causes reduced nut production and copra quality, leading to income loss for smallholder farmers. The resulting economic strain affects local livelihoods and increases management costs. Early detection through remote sensing helps to minimize these losses and supports timely interventions. This study aims to investigate and analyze the spectral characteristics associated with coconut root wilt disease using remote sensing techniques. It focuses on two regions in Tamil Nadu, India Kuzhithurai, Vilavancode Taluk in Kanniyakumari District, and Gudalur Block, Uthamapalayam Taluk in Theni District (Vishwanathan *et al.,* 2020; Vasanthi *et al.,* 2021; Nair *et al.,* 2021). This study uses Sentinel-2A imagery, GIS, and ground truth data to effectively detect coconut root wilt disease in Vilavancode and Gudalur, Tamil Nadu. Its non-invasive, scalable method leverages spectral analysis, especially in the NIR and red-edge bands, for early stress detection. The research emphasizes the economic benefits of early diagnosis for small farmers and supports targeted disease management through spatial mapping. Overall, it offers a valuable, practical approach for remote sensing–based plant disease monitoring. The objective of the present study is aimed to monitor and identify the healthy and diseased coconut palms in the study area from the satellite data and to generate spectral signature to differentiate between healthy and diseased coconut in the study area.

STUDY AREA

The study focuses on two regions in Tamil Nadu, India: Kuzhithurai region, Vilavancode Taluk in Kanniyakumari District and Gudalur Block, Uthamapalayam Taluk in Theni District (Figure 1). Kuzhithurai, Vilavancode Taluk is located at latitude 8°18'43.89"N and longitude 77°12'50.20"E. This coastal area lies near the foothills of the Western Ghats, providing a diverse landscape of hills, forests, and rivers. Gudalur Block, Uthamapalayam Taluk is situated in the fertile Cumbum Valley at latitude 9°40'47.73"N and longitude 77°14'50.16"E, with an elevation of 1182 meters. The area is characterized by black and red soils, ideal for agriculture. The average temperatures range between 30.6°C and 40.6°C, and it receives 70.5 cm of rainfall annually, mainly during the southwest monsoon. The study was conducted during the period from January to April 2025, covering the dry season to allow clear satellite imagery acquisition and effective field verification.

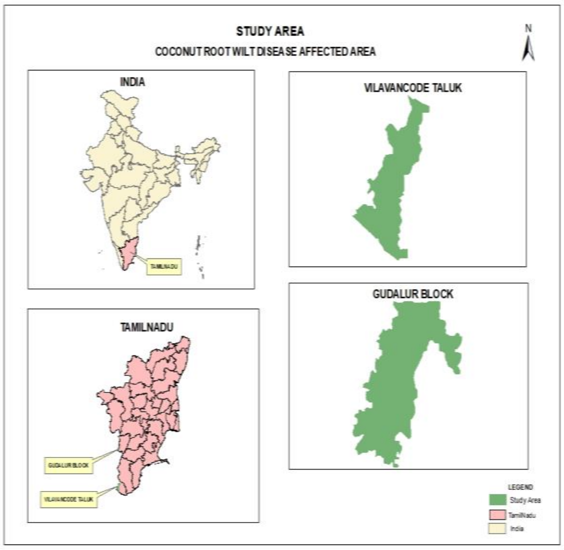

Figure 1 Location of Study Area

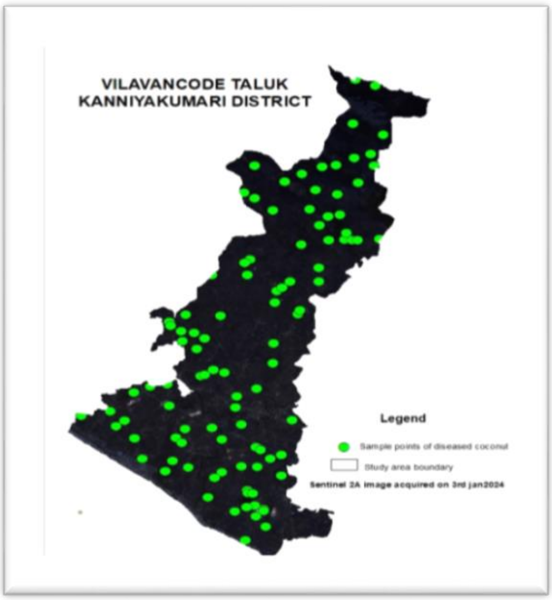

Figure 2 Sample points –Vilavancode Taluk

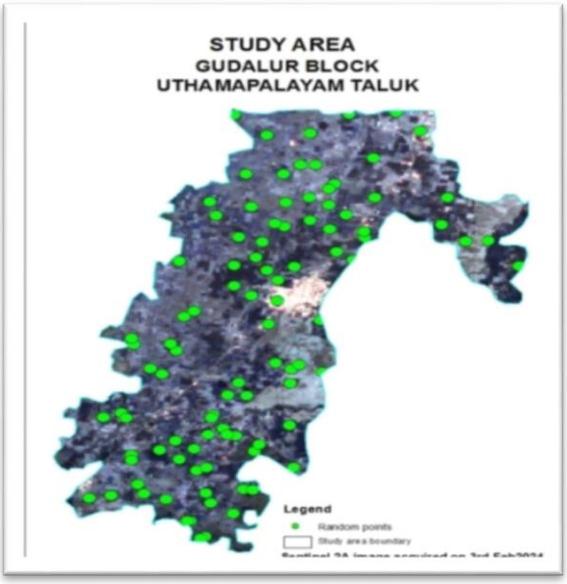

Figure 3 Sample points - Gudalur Block

METHODOLOGY

The study utilized Sentinel-2A imagery and GIS tools to analyze spectral differences between healthy and root wilt–affected coconut plantations in Vilavancode (Kanniyakumari) and Gudalur (Theni). Using QGIS, satellite bands were composited and 100 random sampling points were generated per region (Figure 2 and 3). Spectral profiles for various land cover types were compared, revealing distinct signatures for healthy versus diseased coconut plantations. This integrated remote sensing approach effectively identified root wilt impact. To enhance the accuracy and reliability of the study, ground truth data was incorporated to distinguish healthy and root wilt–affected coconut plantations. Field surveys were conducted in both Vilavancode (Kanniyakumari) and Gudalur (Theni) to collect information on plant health status, confirmed by visual symptoms such as leaf flaccidity, yellowing, and reduced nut yield—typical indicators of root wilt disease. GPS coordinates of identified healthy and diseased trees were recorded and used to validate satellite-based classifications. This ground validation ensured accurate spectral signature interpretation and improved the robustness of remote sensing analysis.

RESULTS AND DISCUSSION

In the visible region (0.4–0.7 µm), strong absorption due to chlorophyll pigments shows notable absorption peaks at 0.43 µm & 0.66 µm (chlorophyll a) and 0.45 µm & 0.65 µm (chlorophyll b). The minimal reflectance around 0.54 µm, contribute to the green appearance of healthy foliage. In the near-infrared region (0.7–1.2 µm) the high reflectance (40–60%) due to healthy mesophyll structure, indicate strong scattering and low absorption (Figure 4a and b).

The diseased palm in the visible region due to reduced absorption at chlorophyll bands, indicate decreased chlorophyll and overall vitality (Figure 4a). In the near-infrared region (500–1100 nm) significantly lower reflectance due to mesophyll damage and water loss occurs, reflecting physiological stress of the diseased areas as shown in the Figure 8 and 9. Healthy trees (e.g., Sample Points 24, 64, 3, 48, 69, 36 and 44) show high NIR reflectance and distinct spectral peaks, indicating healthy foliage and optimal photosynthetic activity. Diseased trees (e.g., Points 73, 77, 64, 81) show flattened or sharply declining NIR reflectance, a marker of root wilt stress and impaired water/nutrient uptake (Figures 4a and 4b).

Settlements (Figure 5) show distinct, stable spectral reflectance with minimal variability, making them easily distinguishable from vegetated areas such as coconut plantations, banana fields, areca nut groves, paddy fields, and mixed forest patches. These vegetated areas exhibit dynamic spectral responses, especially in the visible and near-infrared ranges, due to differences in chlorophyll content, canopy structure, and moisture levels. Fallow land (Figure 6) exhibits high reflectance across 0.4–1.2 µm due to exposed soil and lack of vegetation. Other Vegetation (Figure 7) displays unique spectral patterns in the visible to near-infrared range, allowing differentiation from coconut plantations. Fallow land (Figure 6) exhibits high reflectance across 0.4–1.2 µm due to exposed soil and lack of vegetation. Other vegetation (Figure 7), such as banana, areca nut, and mixed forest patches, displays unique spectral patterns—characterized by strong chlorophyll absorption in the blue (~0.45 µm) and red (~0.67 µm) bands, and a pronounced peak in the near-infrared

(~0.85 μm) due to healthy leaf structure. These spectral traits differ from coconut plantations, which typically show a moderate NIR reflectance and distinct red-edge response. This enables reliable differentiation of vegetation types in multispectral imagery. Near-infrared reflectance is an indicator (Figures 4a, 4b, 8) showing a clear decline in NIR reflectance in diseased coconut trees and is linked to leaf mesophyll damage, chlorophyll loss and reduced water retention are strong marker of root wilt disease.

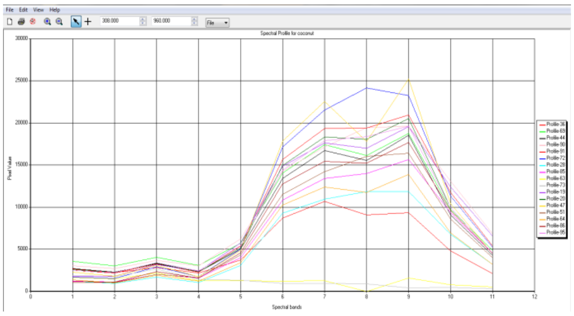

Figure 4a Spectral profiles showing healthy and diseased coconut in Vilavancode

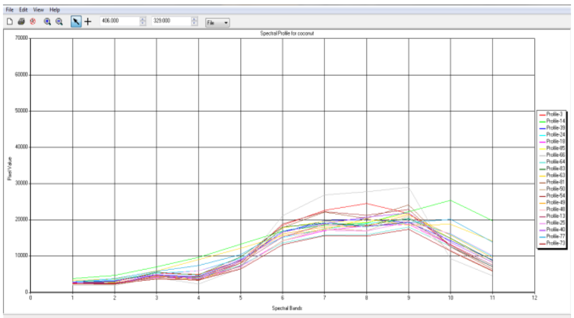

Figure 4b Spectral profiles showing healthy and diseased coconut in Gudalur

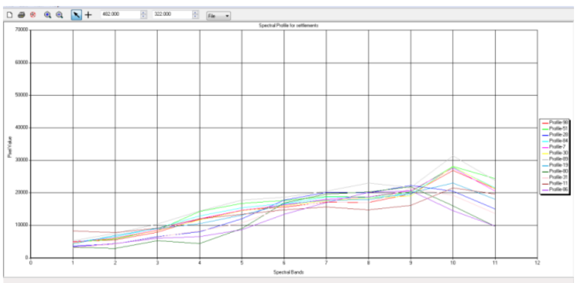

Figure 5 Spectral profiles showing settlements

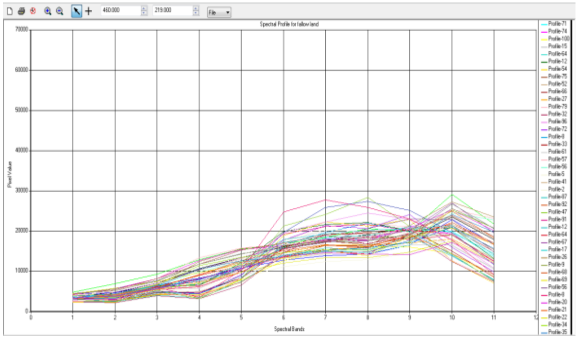

Figure 6 Spectral profiles showing Fallow lands

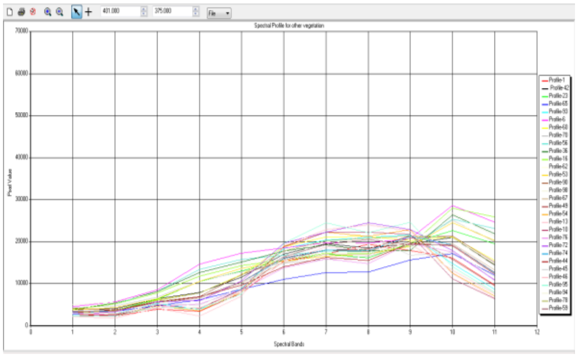

Figure 7 Spectral profiles showing other vegetation

Spectral Analysis provides a non-invasive and effective tool for early detection, enabling timely and targeted interventions. The combination of remote sensing and ground truth increases detection accuracy and supports spatial disease mapping for better resource management. The findings support sustainable agriculture and the use of spectral tools to promote resilient coconut farming, especially in vulnerable areas like Vilavancode and Gudalur.

Remote sensing techniques reveal clear spectral differences between healthy and diseased coconut plantations, providing an effective method for early detection and spatial mapping of root wilt disease (Figure 9).

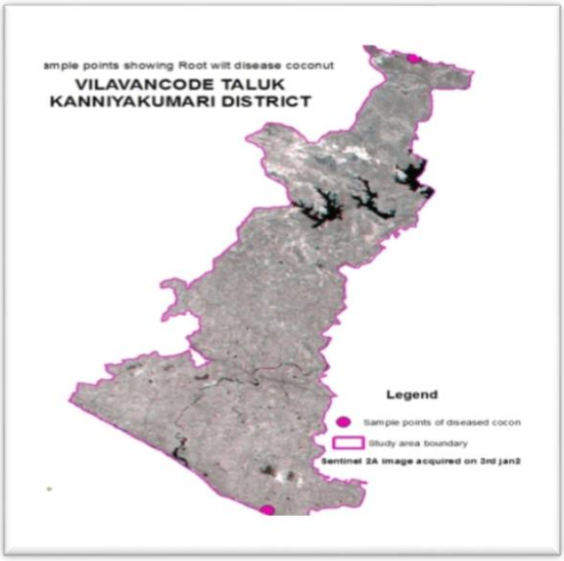

Figure 8 Layout showing the root wilt disease coconut

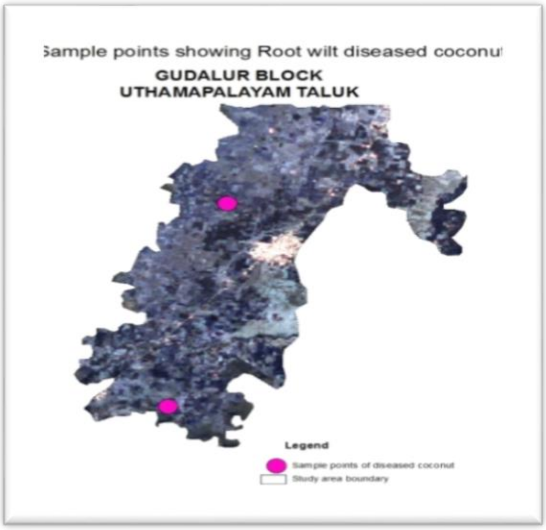

Figure 9 Layout showing the root wilt disease coconut

Spectral analysis allows for identification of diseased regions even before visible symptoms (like leaf wilting or yellowing) appear. It is non-invasive and efficient for large-scale monitoring of plantation health. Integration with ground truth data enhances detection accuracy and supports the creation of disease-specific spectral indices, improving identification of disease hotspots. Key indicators include reduced reflectance in the near-infrared (NIR) region due to compromised leaf structure and increased reflectance in the red and shortwave infrared (SWIR) bands, associated with chlorophyll degradation and moisture loss. These spectral signatures, when correlated with field-verified data, provide a reliable basis for early detection and spatial mapping of root wilt disease. This approach supports targeted interventions, efficient resource allocation, and proactive management of plantations to minimize economic loss. The study confirms that remote sensing technologies (supported by spectral signatures from Figures 4a, 4b, 8, and 9) are highly effective in the monitoring of the health coconut tree and supporting sustainable agriculture practices in disease-prone regions like Vilavancode and Gudalur.

The spectral analysis in Gudalur (Theni) and Vilavancode (Kanniyakumari) revealed clear differences in reflectance patterns between healthy and diseased coconut plantations. Diseased trees exhibited reduced chlorophyll absorption and lower NIR reflectance (0.5–1.1µm), signaling stress, structural damage, and impaired photosynthesis. Fallow land and sparse vegetation showed higher reflectance typical of bare ground. These spectral distinctions enable early, non-invasive detection and spatial mapping of root wilt disease, supporting more effective monitoring and sustainable management of coconut plantations.

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