Analysis of changes in oil palm canopy architecture from basal stem rot using terrestrial laser scanner

ABSTRACT

Basal stem rot (BSR), caused by the Ganoderma fungus, is an infectious disease that affects oil palm (Elaeis guineensis) plantations. BSR leads to a significant economic loss and reductions in yields of up to Malaysian Ringgit (RM) 1.5 billion (US$400 million) yearly. By 2020, the disease may affect ∼1.7 million tonnes of fresh fruit bunches. The plants appear symptomless in the early stages of infection, although most plants die after they are infected. Thus, early, accurate, and nondestructive disease detection is crucial to control the impact of the disease on yields. Terrestrial laser scanning (TLS) is an active remote-sensing, noncontact, cost-effective, precise, and user-friendly method. Through high-resolution scanning of a tree's dimension and morphology, TLS offers an accurate indicator for health and development. This study proposes an efficient image processing technique using point clouds obtained from TLS ground input data. A total of 40 samples (10 samples for each severity level) of oil palm trees were collected from 9-year-old trees using a ground-based laser scanner. Each tree was scanned four times at a distance of 1.5 m. The recorded laser scans were synched and merged to create a cluster of point clouds. An overhead two-dimensional image of the oil palm tree canopy was used to analyze three canopy architectures in terms of the number of pixels inside the crown (crown pixel), the degree of angle between fronds (frond angle), and the number of fronds (frond number). The results show that the crown pixel, frond angle, and frond number are significantly related and that the BSR severity levels are highly correlated ($R2 = 0.76$, $P < 0.0001$; $R2 = 0.96$, $P < 0.0001$; and $R2 = 0.97$, $P < 0.0001$, respectively). Analysis of variance followed post hoc tests by Student–Newman–Keuls (Newman–Keuls) and Dunnett for frond number presented the best results and showed that all levels were significantly different at a 5% significance level. Therefore, the earliest stage that a Ganoderma infection could be detected was mildly infected (T1). For frond angle, all post hoc tests showed consistent results, and all levels were significantly separated except for T0 and T1. By using the crown pixel parameter, healthy trees (T0) were separated from unhealthy trees (moderate infection [T2] and severe infection [T3]), although there was still some overlap with T1. Thus, Ganoderma infection could be detected as early as the T2 level by using the crown pixel and the frond angle parameters. It is hard to differentiate between T0 and T1, because during mild infection, the symptoms are highly similar. Meanwhile, T2 and T3 were placed in the same group, because they showed the same trend. This study demonstrates that the TLS is useful for detecting low-level infection as early as T1 (mild severity). TLS proved beneficial in managing oil palm plantation disease.

Keyword: LiDAR; Oil palm architecture; Ganoderma; Crown; Frond