

ABSTRACT

Over the past 20 years, tea productivity has continued to decline, despite tea being one of Indonesia's main plantation commodities. Prolonged drought, pest attacks, and inadequate crop monitoring are contributing factors. Traditional estimation techniques still rely heavily on manual surveys, which are costly, time-consuming, and prone to human error, especially in large plantations with complex canopy structures and terrain. Ineffective management and rising production costs are caused by a lack of accurate plant population data, which directly impacts resource allocation decisions such as fertilizer distribution and replanting programs. There is an urgent need for more precise, systematic, and non-invasive methods of tea plant population estimation, as plant population density significantly affects crop yield.

To address this challenge, this study employs a Stepped Frequency Continuous Wave (SFCW) radar integrated with a Structural Similarity Index (SSIM)-based analysis framework. The SFCW radar was chosen due to its ability to capture frequency responses across a wide band, enabling the detection of reflections associated with structural variations such as tea stalk density beneath dense foliage. The radar data were first processed using low-pass filtering with several cutoff frequencies to investigate their influence on stalk-related reflections. The filtered and unfiltered B-scan images were compared using SSIM, which evaluates similarity based on luminance, contrast, and structure. SSIM maps were then transformed into binary images through thresholding, followed by horizontal averaging along the scanning path, low-pass filtering for noise suppression, and peak detection to identify potential stalk positions. Field validation was conducted by manually counting stalks in plantation rows, providing ground truth for comparison with radar-derived estimates.

The results demonstrate that the proposed approach is capable of consistently detecting stalk positions and mapping tea plant distributions. Among the tested filtering parameters, the cutoff frequency of 180 MHz was found to provide the best balance between noise suppression and retention of key structural reflections, ensuring stalk-related information is preserved. The use of SSIM proved effective in maintaining structural integrity during filtering, thereby improving detection reliability. Overall, this study shows the feasibility of using SFCW radar combined with SSIM-based analysis as a systematic, non-invasive, and efficient method for estimating tea plant populations. These findings not only contribute a novel methodological approach but also highlight the potential for future UAV-based SFCW radar systems to enable large-scale, real-time monitoring of tea plantations, supporting more sustainable and efficient agricultural management.

Keywords – Tea, Productivity, Estimation, Population, Radar.