Thermal Remote Sensing for Monitoring Rice Growth Patterns in Punjab, Pakistan

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Location: SATEYE Company Headquarters, Lahore, Pakistan.

Executive Summary:

SATEYE Company conducted an extensive study to monitor the growth of rice plants (Oryza sativa) across key districts of Punjab, Pakistan, including Sheikhupura, Nankana Sahib, Lahore, Gujranwala and Hafizabad. Recognizing that temperature has a critical impact on rice phenology, the study used Landsat 7 and 8 thermal satellite datasets to calculate pixel-based temperature values and evaluate growth patterns throughout the rice crop's development stages. The analysis revealed spatial variability in growth rates, showing areas with optimal growth, stressed plants and regions with slow growth due to water bodies or urban influences. The results demonstrate the ability of remote sensing and GIS techniques to monitor rice growth efficiently over large areas, offering valuable guidance to farmers, planners, and policymakers for improving crop management, increasing yields, and adapting to the challenges of global warming.

Introduction:

Rice is the second most important staple food in Pakistan and contributes significantly to the national economy, accounting for nearly 1.3–1.6% of the country's GDP. Punjab, particularly the eastern districts, is famous for producing high-quality rice varieties like Basmati, which have high export value. Over the decades, rice cultivation in Pakistan has expanded significantly, both in area and production. However, rice productivity is highly sensitive to environmental conditions, especially temperature. Low temperatures can delay growth, while high temperatures can stress plants, reduce height, and affect yield. This variability means that crops sown at the same time in different regions may reach maturity at different periods, complicating harvesting and management schedules.

SATEYE Company identified the need to evaluate how temperature variations across space affect rice growth. The study focused on key rice-producing districts in Punjab, characterized by fertile plains, temperate to arid climate, and significant temperature variations due to urbanization and proximity to water bodies. By leveraging satellite-based thermal data, SATEYE aimed to map temperature-related growth variability and provide actionable insights for optimal crop management. The study sought to connect scientific monitoring with practical agricultural planning, demonstrating how advanced technology can support both farmers and policymakers in addressing climate-induced challenges in rice production.

Methodology:

The research conducted by SATEYE Company employed remote sensing and GIS techniques to monitor rice growth at various phenological stages. The team used Landsat 7 and 8 thermal datasets, freely available from Earth Explorer, to calculate pixel-based temperature values across a total study area of 13,480 km². Two thermal bands from Landsat 8 (B10 and B11) were used to obtain precise surface temperatures, and these were converted from raw DN values into radiance and irradiance to calculate accurate temperature per pixel. This approach allowed the company to produce a spatially detailed temperature map over the study area.

To monitor growth stages, SATEYE identified sequential stages of rice development: germination, seed establishment, vegetative growth (leaf emergence and tillering), reproductive stages (heading/anthesis), and ripening. Temperature thresholds for each stage were applied to classify areas as optimal, stressed, or slow-growing. The NDVI time series was used to determine the start of the growing season, ensuring synchronization between satellite observations and rice phenology. The team also analyzed histograms of temperature distributions to confirm the prevalence of optimal temperature ranges for growth and to identify regions experiencing stress due to high or low temperatures.

Particular attention was given to urban areas and locations near water bodies. Urban zones with higher temperatures showed accelerated plant stress due to heat and environmental pollution, while water-adjacent regions experienced cooler temperatures that slowed growth. By combining spatial temperature data with phenological stages, SATEYE was able to map heat-induced growth variability and provide a detailed view of rice development patterns across the study area.

Outcomes:

The study by SATEYE Company revealed substantial spatial variability in rice growth across the eastern districts of Punjab. Approximately 7,960 km² of the area experienced optimal temperature ranges, supporting healthy growth during all stages of development. About 4,944 km² of the area was subjected to high temperatures near urban centers, resulting in stressed and short-heighted plants with potentially lower yields. Additionally, 484 km² of land, mainly near water bodies, had low temperatures, causing slower growth rates and delayed maturity.

The results highlighted how temperature significantly influences germination, seed establishment, leaf emergence, tillering, heading, anthesis, and ripening stages. For instance, germination occurred faster at higher temperatures, while high heat during the ripening period

increased respiration rates, reduced carbohydrate accumulation in grains, and negatively impacted final yield. The study demonstrated that rice sown at the same time in different areas reaches maturity at different times due to local temperature variations.

This work confirmed that remote sensing and GIS techniques are highly effective for large-scale, spatio-temporal monitoring of crop growth. The findings provide actionable insights for farmers to optimize sowing schedules, irrigation, and harvesting. Policymakers and agricultural planners can also use these results to implement interventions that mitigate the negative effects of extreme temperatures. Overall, the study emphasizes the potential of satellite-based monitoring to enhance rice productivity, support sustainable agriculture, and address climate change impacts, proving the value of SATEYE Company's technology-driven approach in serving both agricultural stakeholders and society at large.