Farm Zone Management Using TI-NDVI and Fuzzy Clustering

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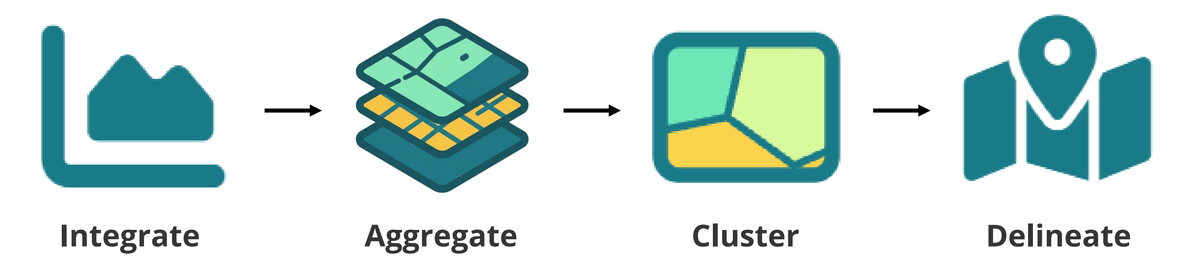
Abstract

To improve the statistical separation of management zones and offer a straightforward entry point for site-specific crop management, this study applies a fuzzy c-means clustering framework to multi-year vegetation metrics. The absence of historical yield data frequently hinders the accurate delineation of agricultural productivity zones. To overcome this limitation, time-integrated NDVI (TI-NDVI) was evaluated as a practical alternative. Analysing these multi-year datasets mitigates seasonal variation, establishing a stable agronomic baseline. Furthermore, applying minimum membership thresholds filters boundary ambiguity, accounting for the continuous environmental gradient.

Problem statement

Without reliable historical yield data, single-season climate noise hinders farm businesses from delineating the stable productivity zones required to effectively implement variable rate technology (VRT).

Workflow



Integrate

Calculates the area under the NDVI curve for the growing season, quantifying total biomass.

Aggregate

Averages data across multiple seasons to filter out interannual climate noise, establishing a stable baseline of productivity.

Cluster

Applies spatial clustering algorithms to group areas of the field that share similar cumulative growth patterns.

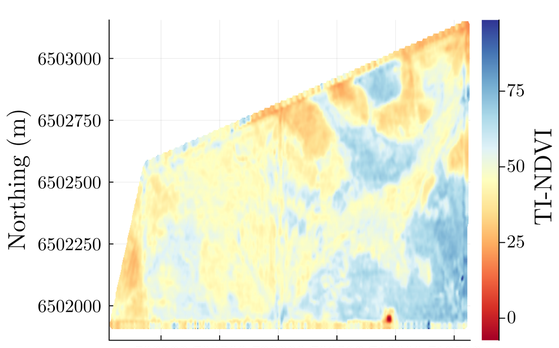
Delineate

Translates these spatial clusters into predictive yield zones, providing a reliable map for targeted agronomic interventions.

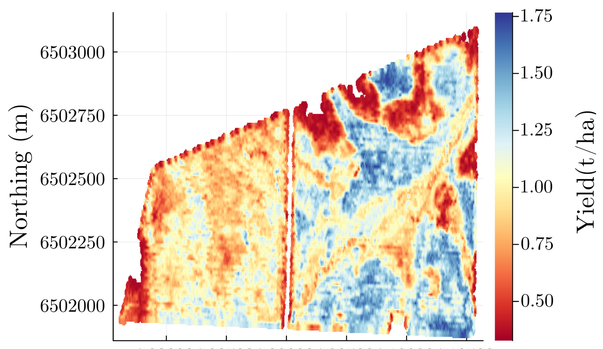
CASE STUDY • Yilgarn • Wheat 2019, 2021, 2022, 2024

INTEGRATE: Kriging interpolation

- A kriging interpolation algorithm was used to align the spatial resolution for direct pixel-to-pixel comparison of cleaned yield and TI-NDVI datasets onto a common uniform grid.
- A visual comparison of TI-NDVI and yield maps shows clear spatial correlation: Areas with high seasonal biomass closely match the high-yielding zones.
- This strong agreement confirmed TI-NDVI as a reliable and logical proxy for predicting yield zones.



TI-NDVI (The area under the NDVI curve) - 2019



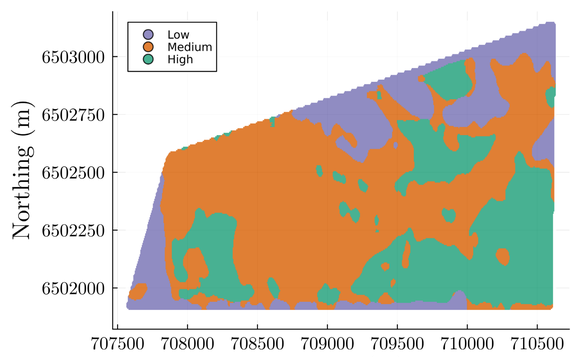
Wheat Yield - 2019

AGGREGATE: Multi-year analysis to establish a stable baseline

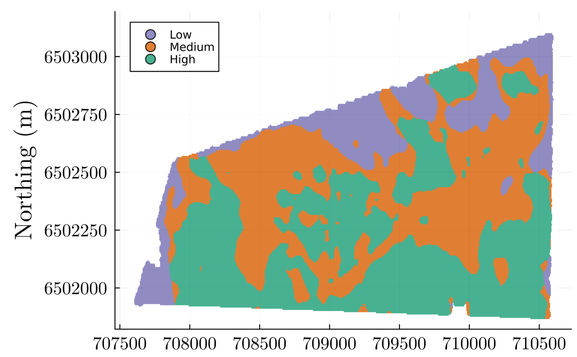
- **<u>Mitigating Inter-Annual Noise</u>:** Relying on a single growing season introduces classification risks due to seasonal and climate variability. Aggregating TI-NDVI data across multiple seasons effectively incorporates climatic variability into the analysis.
- **<u>Revealing Intrinsic Productivity</u>:** Averaging data over multiple seasons reveals the field's consistent and underlying productivity, likely driven by soil type and topography.
  These zones offer a practical and reliable foundation for planning long-term variable-rate applications.

CLUSTER: Discrete zone delineation using spatial k-means

- **<u>Visual Concordance</u>:** The spatial k-means framework effectively partitions the field into three distinct productivity zones, visually capturing the same fundamental spatial patterns as actual yield maps.

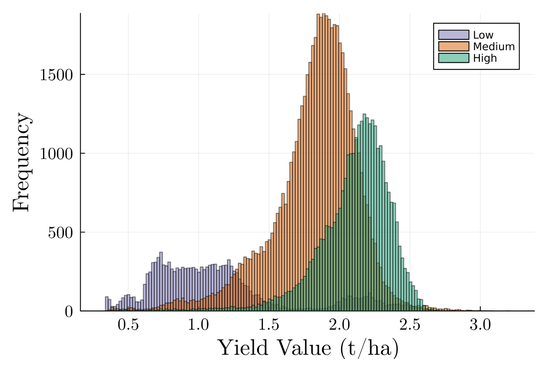


Spatial k-means clustering applied to mean TI-NDVI



Spatial k-means clustering applied to corresponding average harvested yield data

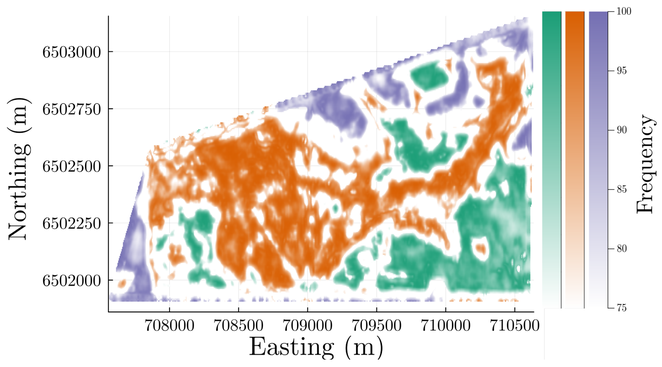
- **<u>Histogram Analysis and Limitations</u>:** Despite this visual agreement, the corresponding yield histogram reveals substantial overlap across intermediate ranges. This demonstrates that rigid 'hard' clustering results in poor class separation by forcing continuous environmental gradients into absolute categories, highlighting the need for a probabilistic approach.



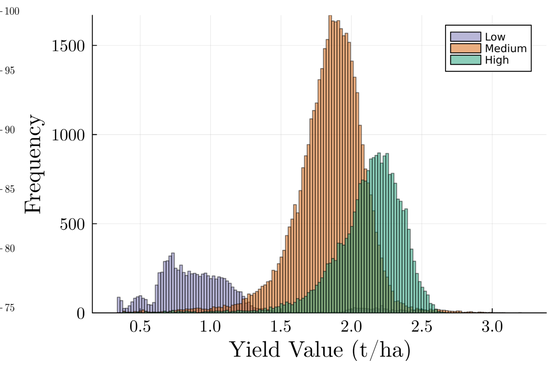
Histograms of actual crop yield values corresponding to each TI-NDVI spatial zone

DELINEATE: Probabilistic zone refinement using fuzzy clustering

- **<u>Embracing Gradual Transitions</u>:** Unlike rigid 'hard' clustering, the fuzzy approach calculates a membership degree for each pixel, reflecting the natural, continuous variability of the field without forcing artificial boundaries.
- **<u>Minimising Yield Overlap</u>:** Applying progressive membership thresholds systematically excludes ambiguous transitional pixels.
  As the certainty requirement increases, overlap between adjacent productivity classes progressively decreases.



Spatial fuzzy c-means clustering on the multi-year mean TI-NDVI using a 75% certainty and above



The corresponding frequency histograms of the averaged actual crop yield values

Impact

By transforming multi-year NDVI data into TI-NDVI and probabilistic management zones, this framework provides farm businesses with the statistical confidence needed to implement targeted agronomic interventions, even without historical yield records.

Acknowledgment

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