

Research question



Does field-specific phenology alignment improve
winter wheat grain protein prediction
over fixed calendar windows?
Field-level winter wheat
grain protein concentration



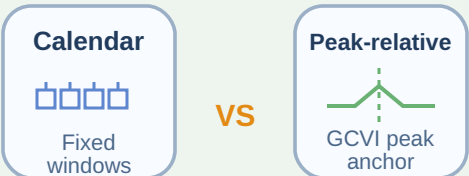
Study data and inputs



Sentinel-2 + vegetation indices
ERA5-Land meteorology
gSSURGO soils + 3DEP terrain
228 commercial winter wheat fields
western Kansas, 2024-2025



Temporal framework



vs

6 strategies tested:
2 alignments × 3 resolutions
monthly, biweekly, periods
Peak date detected from GCVI
calendar vs peak-relative



Best result



+20%

Best model: RF with
peak-relative monthly M+1
(~15-45 d after GCVI peak)

$R^2 = 0.304$
20% above best
calendar strategy ($R^2 = 0.253$)



Key drivers and practical utility



Key drivers

SWIR indices (NBR2, MIRBI)
grain-filling weather (Tmax, dewpoint)
topsoil organic matter



Practical utility

for grain elevators, farmers, and milling industry

- Supply Chain and Milling Logistics
- Early-Season Quality Segregation
- Strategic Marketing

enabled by 3-class quality prediction (47-49% accuracy)