Can NDVI and $ReNDVI_{750}$ be a Reliable Predictor of Grain Yield for Corn Grown on Landscape Positions with Split Nitrogen Application Timings ?

Pranay Kumar Kadari[1], Gurbir Singh[1], Kelly A. Nelson[1], Morgan Davis[2], Gurpreet Kaur[2]

[1]Division of Plant Sciences and Technology, College of Agriculture, Food and Natural Resources

[2]School of Natural Resources, College of Agriculture, Food and Natural Resources

University of Missouri, Columbia, Missouri, USA.

Introduction

- Terracing on claypan has proved to be beneficial for soil conservation and helps promoting successful crop production on landscape with slope.
- Reshaping of slope within a terrace primarily disrupts the soil structure due to the disturbance caused by the earthworks conducted during the construction of terraces and leads to increased variability in soil properties (Liu et al., 2011).
- Differences in soil fertility within a terraced field requires site specific management of inputs.
- Nitrogen (N) fertilizers, alone costs around 30% of total input costs and is sensitive to different environmental losses on claypan terraces (Adler et al 2020). Therefore, categorizing terraces into different variability classes using the Topographic Positioning Index (TPI) and employing various correlation models with different spectral indices to address inter-terrace soil variability can significantly enhance crop management decisions for produces.

Objectives

- To assess the yield variability across three topographic positions within a terraced field and correlate Corn grain and corn biomass yield with NDVI and $ReNDVI_{750}$ using different regression models.
- To evaluate if split N application can improve the nitrogen fertilizer use efficiency for terraced field.

Methodology

- The field experiment was established in 2022 at the Lee Greenley Jr. Memorial Research Farm (40º02'1.65'' N, 92º19'0.34'' W) in Novelty, MO.
- The study site represented a section of a parallel terrace of 73 meters (240 fts) in length built in 1981 and dominant soil series at the study site was Kilwinning silt loam (Fine, smectitic, mesic Vertic Epiaqualfs).
- Terrace was classified into topographic positions based on TPI Values and three slopes i.e., Shoulder (S), Backslope (BS) and Footslope (FS) were identified similar to Singh et.al.,(2020) Figure 1.
- Four N timing treatments were all N applied at preplant, 50% N applied at preplant and 50% at V6, 50% N applied at preplant and 50% at V9, and zero N control (NTC).
- Nitrogen was broadcasted as Super-U at a rate of 187 kg N ha^{-1}.
- All N treatments were replicated three times on each topographic position within a plot size of 3.04 m x 9.14 m and a row spacing of 76.2 cm.
- Corn was planted on April 16th, 2023, and aboveground biomass was collected at R2 growth stage of corn.
- Corn grain yield, moisture and test weight were collected with a plot combine equipped with a grain gauge.
- Multi-spectral imagery with 7 bands was obtained using DJI MAVIC 3E Multispectral drone at R1 stage of crop.
- Ortho-mosaic from the drone imagery was generated in Agisoft Metashape Professional v2.0 and Spectral indices such as NDVI and $ReNDVI_{750}$ were obtained for each plot from ERDAS Imagine 2020. Analysis for four regression models (linear, quadratic, linear plateau and quadratic plateau) was performed in R Studio v1.4 to assess the regression relationships between spectral indices (NDVI and $ReNDVI_{750}$) and grain and biomass yields obtained from the middle two rows of each plot. Best fit models were selected based on the low AIC and low RMSE for each Topographic position (Table 1).
- Yield data was analysed in SAS v9.4 to determine difference caused due to the main effects of topographic positions and nitrogen timing treatments.

Results and Discussion

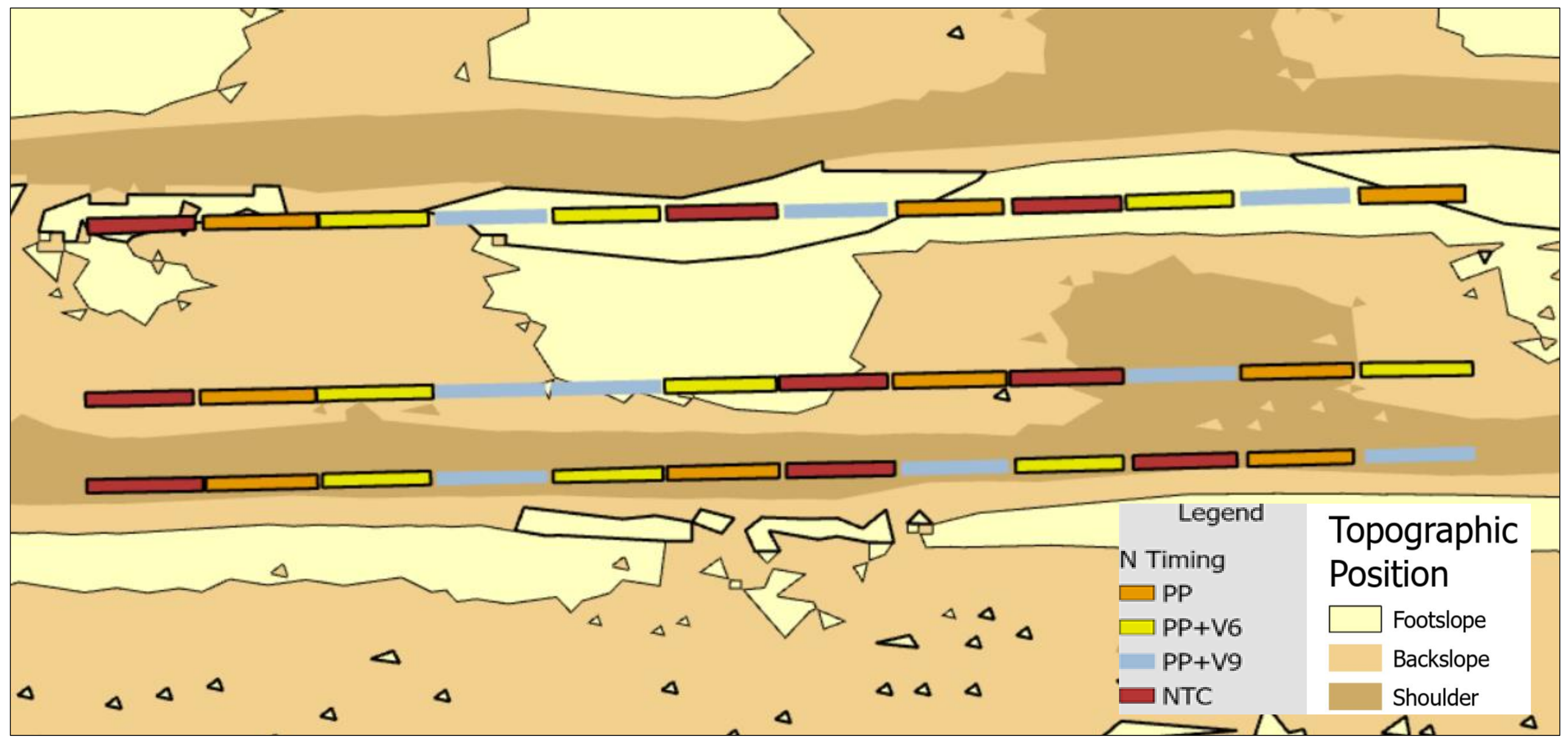

Figure 1. Map representing three topographic positions Shoulder (S), Backslope (BS) and Footslope and different nitrogen application timing treatments.

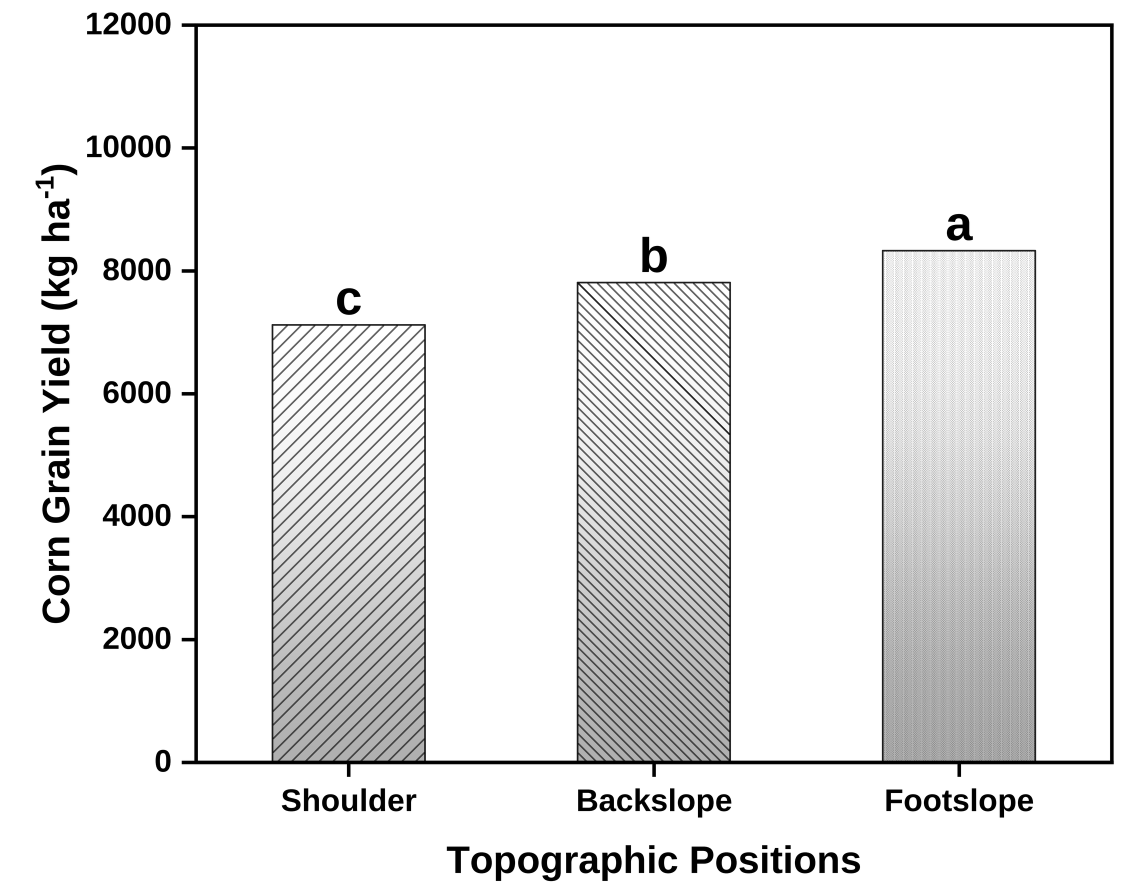

Figure 2. Corn grain yield averaged over the nitrogen application timing treatments.

Table 1: Best fit linear or quadratic model for NDVI and $ReNDVI_{750}$ for corn grain yield and aboveground biomass separated based on the Topographic Positions (Shoulder, Backslope, Footslope). Only the R-squared value of the best models are shown in the tables.

Grain Yields					
Topographic Position	Predictor	Best Model	R-squared Value	AIC	RMSE
Shoulder	NDVI	Quadratic	0.8209	201.76	776.35
Backslope	NDVI	Quadratic	0.8622	202.08	786.84
Footslope	NDVI	Quadratic	0.8247	199.13	695.76
Shoulder	ReNDVI	Quadratic	0.8559	199.15	696.34
Backslope	ReNDVI	Quadratic	0.8904	199.33	701.49
Footslope	ReNDVI	Quadratic	0.8410	197.95	662.49

Biomass Yields					
Topographic Position	Predictor	Best Model	R-squared Value	AIC	RMSE
Shoulder	NDVI	Quadratic	0.6453	223.55	1925.02
Backslope	NDVI	Quadratic	0.1824	240.36	3877.05
Footslope	NDVI	Linear	0.7456	213.69	1386.94
Shoulder	ReNDVI	Linear	0.6331	223.96	1957.95
Backslope	ReNDVI	Quadratic	0.2025	240.06	3829.05
Footslope	ReNDVI	Linear	0.7271	216.53	1436.48

- Corn grain yields were significantly higher for footslope topographic position compared to backslope and shoulder (Figure 2). The interaction effect of nitrogen application timings and topographic positions was non-significant ($p>0.05$).
- Year 2023 was a drought year for northeast Missouri. Therefore, corn grain yield did not show a typical grain yield response of topographic position where shoulder topographic positions generally yield better than the backslope and footslopes (Adler et al. 2020 and Kaur et al. 2023).
- NDVI and $ReNDVI_{750}$ showed weak positive correlations with biomass yields across landscape positions, with R^2 values ranging approximately from 0.58 to 0.61 for SH, BS, and FS, respectively. In contrast, strong positive correlations were observed between grain yields and NDVI/ $ReNDVI_{750}$, with R^2 values consistently exceeding 0.7 across all three topographic positions.
- The best-fit models for predicting grain yields using NDVI and $ReNDVI_{750}$ were quadratic models with high R^2 values (e.g., Backslope NDVI: $R^2 = 0.8622$). Quadratic models were also effective for biomass yields (e.g., Shoulder NDVI: $R^2 = 0.6453$).
- $ReNDVI_{750}$ generally showed better performance than NDVI for grain yields (e.g., Backslope $ReNDVI_{750}$: $R^2 = 0.8904$).
- For biomass yields, both linear and quadratic models performed similar, depending on the topographical position (e.g., Footslope $ReNDVI_{750}$: $R^2 = 0.7271$).
- Models including Quadratic plateau and Linear Plateau might not be suitable for the data due to their lower flexibility, which prevents them from capturing the non-linear relationships between the predictors (NDVI, $ReNDVI_{750}$) and the response variables (grain yield, biomass yield). Linear models, for instance, may oversimplify these relationships, leading to poor fit and lower R^2 values.
- Additionally, models like the Linear Plateau assume a piecewise linear relationship, which may not accurately reflect the true data pattern. Consequently, these models exhibit higher RMSE values, indicating larger deviations from the actual observed values. Hence, the Quadratic models provide a better fit for this data set (Smith and Draper, 1998).

Conclusions

- Quadratic models best predict grain and biomass yields using NDVI and $ReNDVI_{750}$ at different topographic positions, with high R^2 values and lower AIC and RMSE Values.
- NDVI and $ReNDVI_{750}$ emerge as reliable indices for predicting grain yields rather than biomass yields at the R1 stage of corn using Quadratic linear model.

References

- ESRI 2011. ArcGIS Desktop: Release 10. Redlands, CA: Environmental Systems Research Institute.
- ERDAS (2014) ERDAS Imagine 2014. Hexagon Geospatial, Peachtree Corners Circle Norcross.
- Kaur, H., Nelson, K. A., Singh, G., Kaur, G., & Grote, K. (2023). Landscape position and cover crops affects crop yields in a terrace-tiled field. Agricultural Water Management, 289, 108517.
- Adler, R. L., Singh, G., Nelson, K. A., Weirich, J., Motavalli, P. P., & Miles, R. J. (2020). Cover crop impact on crop production and nutrient loss in a no-till terrace topography. Journal of Soil and Water Conservation, 75(2), 153-165.
- Draper, N. R., & Smith, H. (1998). Applied regression analysis (Vol. 326). John Wiley & Sons.

Acknowledgement : Funding for this research was provided by the University of Missouri Agriculture Experimental Stations and Greenley Research Center, Novelty, MO.