Modeling Environmental Impacts on Rice Growth Phases Using Spatial Analysis

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INTRODUCTION

Climate change and varying environmental conditions endanger crop stability. Understanding the factors that influence crop growth and being able to predict these changes are important for farmers and breeders alike.

***Oryza sativa* (rice)**

Rice growth occurs in distinct phases such as vegetative, reproductive, and ripening. Vegetative is the initial growth stage from germination to panicle initiation, reproductive is Each phase is also sensitive to different environmental factors such as temperature and precipitation.

We aim to bridge the gap between environmental science, agronomy, and spatial analytics through understanding rice growth and the impacts the environment can have in order to improve cultivation strategies and improve global food security initiatives.

AIM

Modeling the effects of environmental covariates such as precipitation, temperature, potential evapotranspiration on the growing phases such as vegetative, reproductive, and ripening and developing predictive models to forecast phase durations under different environmental scenarios.

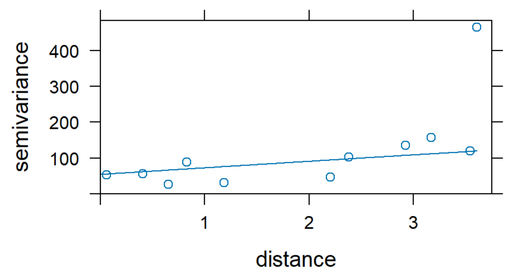
This project aims to analyze spatial autocorrelation of environmental values and growth phase durations, investigate the relationship between environmental covariates and rice growth phases using spatial models, and predict the impact of environmental changes on rice growth in different locations using geographically weighted regression and kriging.

METHOD

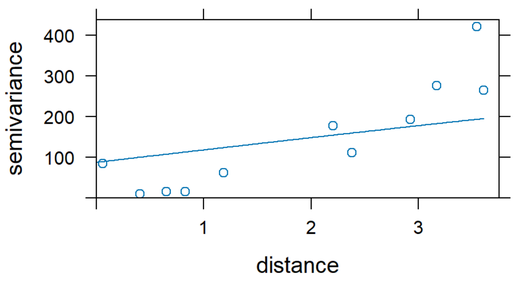
- Data preprocessing
  - Converting Easting and Northing values into Latitude
  - Calculating growing phase durations from dates
  - Normalizing all environmental covariates for interpretability
- Use semi-variograms to analyze spatial autocorrelation of the environmental covariates and the growth phase durations
- Apply Geographically Weighted Regression to model spatially varying relationships between environmental covariates and growth durations and allows us to account for heterogeneity
- Kriging is used to predict rice growth phase durations in unmeasured locations to estimate theses values in regions where data is unavailable.

VISUALIZATIONS

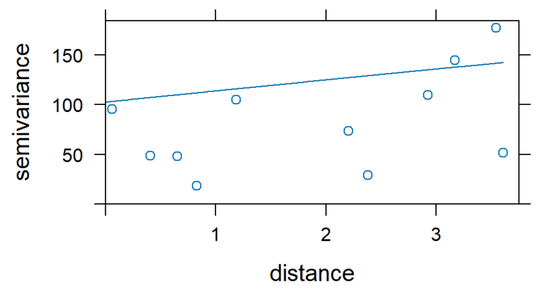
Images



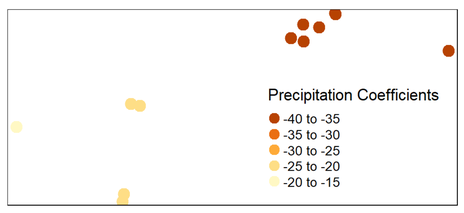
Semi-Variogram of VE_Duration



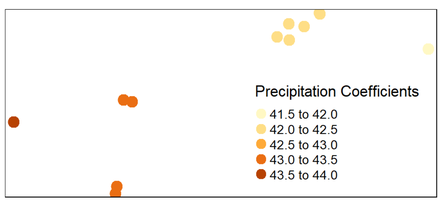
Semi-Variogram of RE_Duration



Semi-Variogram of RI_Duration



Map of GWR results evaluating strength of Precipitation on VE_Duration based on location



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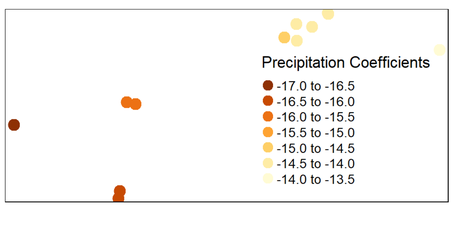
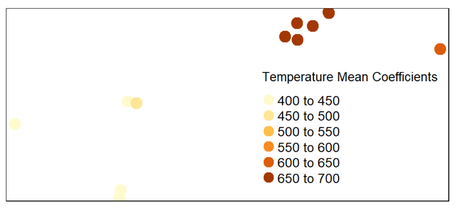
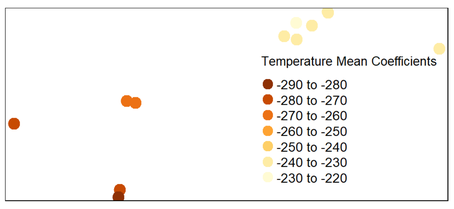


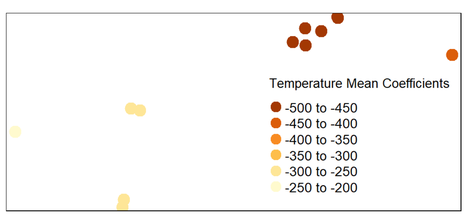
Map of GWR results evaluating strength of Precipitation on RI_Duration based on location



Map of GWR results evaluating strength of Temperature Mean on VE_Duration based on location



Map of GWR results evaluating strength of Temperature Mean on RE_Duration based on location



Map of GWR results evaluating strength of Temperature Mean on RI_Duration based on location

RESULTS

According to the Semi-Variogram of the Vegetative Phase, the range is large as it is hard to tell where the sill starts. We can say that spatial correlation extends over a large distance since there is autocorrelation.

The Semi-Variogram of the Reproductive Phase is the most steep where it goes from less than 100 semivariance to 200. This could mean that there is spatial dependence over the entire distance of increase which shows autocorrelation for these values as well.

The Semi-Variogram of the Ripening Phase has the least steap increase which means that it nearby points could be less correlated than the rest of the phases.

Overall, there seems to be correlation in location of the Vegetative Phase and Reproductive Phase for the rice plants .

The map for the effects of precipitation on the Vegetation phase shows significant clusters of areas where less precipitation effected reduced the duration of the Vegetative phase. Similarly for the other phases as well.

The map for the effects of mean temperature on the phases shows that certain clusters are effected negatively or positively by temperatures, which in turn increase or decrease the duration of the phase. (Values of estimated coefficients for temperature changed due to the selection of the optimal bandwidth).

DISCUSSION

Overall, the visualizations show there is significant autocorrelation with certain environmental variables which effect the duration of the growth phases of *Oryza sativa*.

With this work, researchers can gain better insights into the principles of spatial statistics and it's effects on genomics. Using predictive analytics breeders can consider a changing environment in their understanding of genetics and implement new strategies for future breeding.

Future extensions of this can be used in research for **Genotype-Environment Interaction Analysis** where we can see how genetic traits change or interact with environmental factors which can enhance precision in breeding techniques for more climate and disease resistant crops.

Another application can be in **real-time monitoring using IoT sensors** on-board tractors or combines to gain insights of environmental variables for stages of the crop lifecycle to have precise field management.

ACKNOWLEDGEMENTS

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Nguyen, V.H., Morantte, R.I.Z., Lopena, V. et al. Multi-environment Genomic Selection in Rice Elite Breeding Lines. Rice 16, 7 (2023). https://doi.org/10.1186/s12284-023-00623-6

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