Using the Bayesian approach to quantify the impact of soil silicon availability on rice yield and quality in a Japanese mountainous region

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1. Introduction

Silicon (Si) is an essential nutrient for rice. However, the effect of Si on yield and quality of rice remains largely uncertain in actual farmers' fields. To increase rice productivity and nutrient use efficiency, it might be necessary to develop a field-specific nutrient management strategy for rice fields with a focus on Si availability. However, on-farm data usually has a large uncertainty in parameters which is difficult to be quantified. Thus, this study aimed to explore the factors affecting rice yield and quality including underlying unquantified components such as farmer management block and season using the Bayesian approach. On-farm trials were conducted using a farmers' yield monitor. This study further aimed to provide empirical evidence supporting the practical value of field-specific trials in Japanese paddy fields.

2. Material and Method

The research site was located in Gero City, Gifu Prefecture, Japan (137°12'E, 35°64'N). The variety "Koshihikari" was cultivated for the trials. Fertilization rates varied across 169 fields during a three-year period (2018, 2019, and 2020), with different types and rates used based on the farmer's strategy for each block and season. Consequently, the N input rate ranged from 48 to 75 kg N ha^{-1}. Field-specific data on yield and protein content were collected from commercial yield monitors over the years. Field sizes ranged from 0.035 ha to 0.27 ha, with an average of 0.11 ha. The phosphate buffer method was used to measure soil available Si. The farmer almost uniformly managed fields based on each block. For instance, the transplanting dates were nearly identical within a specific block. Because "Koshihikari" was not grown in block 1 and in 2022, the two blocks in 2022 were not included in the trials and further data analysis. A Bayesian linear regression model was fit in R software using Rstan. Four Markov Chain Monte Carlo (MCMC) chains with 5,000 iterations and a 500-iteration burn-in were run for each model, totaling 18,000 iterations for posterior inference. Chain convergence was monitored using trace plots and R-hat values to ensure the validity of the analysis. The primary explanatory variables were as-block, applied N, available Si, and year.

3. Results and discussions

In this study, we implemented the posterior means and 95% high-density intervals (HDIs) for yield and protein coefficients. The effective sample size for MCMC samplings was sufficient for all coefficients, and the R-hat values, used as convergence indicators, were all within the acceptable range of less than 1.10. Block 4 had the highest yield posterior mean within the 95% HDI threshold, while block 1 had the lowest posterior mean within the 50% HDI range. Furthermore, there were no significant effects of applied N, available Si, or year on rice grain yield at the 95% HDI threshold. For available Si, the high concentration had the highest posterior mean at the 50–80% HDI. Regarding protein concentration, no significant effect was observed at 95% HDI. However, block 4 showed the highest posterior mean of protein concentration at 80% HDI, and blocks 1 and 6 showed the lowest protein concentration within 50% HDI. High applied N and available Si expected high protein levels within the 50% HDI. This study suggests that a high N fertilizer input rate may adversely affect rice grain quality without significantly contributing to production. High available Si might enhance nutrient uptake, potentially increasing yield. Farmers may consider selecting rice grains from blocks 1 and 6 with the lower protein content to obtain a premium price.