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A Study of the effect of Site, Variety, and Fertilizer Application on Growth and Yield Component of Rice: Multivariate Analysis of variance Approach

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Abstract

The study aimed to evaluate the effects of site, variety, and fertilizer application on crop yield through a multivariate analysis of variance (MANOVA). The experiment was conducted across multiple sites with different soil types and environmental conditions. Four distinct crop varieties were selected, and three different fertilizer treatments were applied. Data on various agronomic traits, including plant height, tillering height, and yield, were collected to assess the interactions between the factors. The multivariate analysis of variance result indicates significant finding across various effects and interactions related to site, variety, fertilizer and their combinations. The intercepts terms for all test (pillai's trace, wilks lambda, Hotelling trace and Roy's largest root) were highly significant ($p < 0.001$), confirming that the combined dependent variables differ significantly from zero for the main effects, site and variety showed strong significant in all test statistics with p-value less than 0.001, indicating that both environmental factor(site) and genetic difference(variety) significantly influence the growth and yield of rice. These results highlight the primary importance of site and variety in influencing rice growth with a weaker but notable influence of fertilizer and some potential for variety specific fertilizer responses. The finding emphasizes the importance of selecting appropriate rice varieties and optimizing environmental conditions to achieve better rice productivity. The results highlight the robustness of MANOVA as a tool for agricultural research, especially in evaluating interrelated agronomic traits. The study contributes to the optimization of rice production strategies through multivariate modeling that accounts for environmental and varietal complexity.

Keywords: Site, Variety, Fertilizer and MANOVA

Introduction

In agronomic research, response variables such as plant height, tiller count, and grain yield are often interrelated. Traditional univariate techniques are limited in their ability to capture the true multivariate nature of these relationships, particularly when evaluating complex treatment structures involving site, variety, and fertilizer. The application of Multivariate Analysis of Variance (MANOVA) presents a more robust framework for such evaluations by simultaneously analyzing multiple dependent variables and their response to categorical predictors.

A confluence of environmental, genetic, and managerial elements naturally affects agriculture. To separate the effects of these variables on crop production, a thorough statistical analysis is necessary due to their sometimes-complicated relationships. When it comes to crop development and yield, site, variety, and fertilizer application are crucial considerations. It is not always clear how they interact to affect many agronomic characteristics (including yield, plant height, and tiller height). Researchers can assess these factors' influence on several dependent variables at once using the potent statistical tool known as multivariate analysis of variance (MANOVA).

This subject examines the use of MANOVA in researching how crop performance is impacted by site, variety, and fertilizer treatment. In order to provide insights for improved agricultural practices, the goal is to determine the primary effects and interactions among these elements as well as how they affect agronomic features.

In modern agriculture, optimizing crop yield requires a comprehensive understanding of how various factors interact and influence plant growth. Among the most significance of these factors are site conditions, crop variety, and fertilizer application each of which plays a critical role in determining agricultural productivity. In most statistical experiments here we work on more than one dependent variables as these are often correlated with one another. In these situations, a single overall statistical test that assesses the effects of the independent variables on all of the response variables simultaneously is desired and multivariate analysis of variance (MANOVA) test often mostly preferred to performing multiple individuals (univariate) test. There is also a strong need to explore how the independent variables influence some patterning of response on the dependent variables. This can only be achieved by the use of multivariate analysis of variance. These work therefore evaluates the effects of planting site, variety, and fertilizer on rice plant height, tiller height and yield using MANOVA technique.

A study by Emeana *et al.* (2019) showed that less than12% of organic farmers surveyed in a community in Southeast Nigeria engage incomplete organic farming. Organic certification and government subsidies might provide vital mechanisms that can significantly contribute to expanding organic production among farmers in Nigeria (Ume and Bahta, 2024). Priya and Singh (2024), who studied the market dynamics and potential for organic agriculture in the global South. Despite these valuable contributions, there remains a significant gap in the literature regarding comprehensive investigations into the economic incentives and government support systems, including certifications and subsidies, that are instrumental in scaling up organic agriculture within the global South. There is a noticeable gap in studies that have comprehensively explored if, and which economic incentives and government support systems, including certifications and subsidies, can be instrumental scaling up organic agriculture within the global South. Verburg *et al.* (2022) studied the case of organic dairy farming in the Netherland sand reported that government subsidies bolstered the economic feasibility of organic farming by offering financial support for organic certification fees, organic inputs, and infrastructure development. According to their findings, these subsidies reduce the financial barriers that farmers may face when considering expanding.

According to Zhou *et al.* (2022), organic fertilization practices can yield multiple benefits for rice crop production and soil quality. Such practices have enhanced soil fertility, structure, and nutrient availability while increasing the organic carbon content and providing a nutrient-rich food source for micro-organisms. Applying organic fertilizers can also significantly shift the composition of the microbial community and increase microbial diversity. Furthermore, organic fertilization can alter the soil cation exchange capacity (CEC) and soil moisture content, leading to changes in the community structure and composition of soil fauna in acidic soils. Overall, organic fertilization practices offer a promising alternative to conventional farming systems, promoting sustainable and eco-friendly approaches to agricultural production. Hence, this technology demonstration approach to rice production under organic and inorganic fertilizer application was conducted to evaluate which fertilizer application would give better growth, yield, and lowest production cost per hectare. This study will serve as fertilizer options for rice farmers in utilizing organic, inorganic, or a combination of organic and inorganic in order to reduce the cost of fertilizer inputs.

Dollison (2023). Carried out analysis of inorganic and organic fertilizers application/hectare of rice production particular quantity unit cost, based on the results of the study, it can be concluded that the growth performance tested was not significantly affected by the kind and amount of inorganic and organic fertilizer application. Andriatmoko (2020) analyzed the effect of the use of organic rice and inorganic rice production factors in Sambirejo sub-district, Sragen Regency, analyzed the level of efficiency in organic and inorganic rice farming production and compared the level of production benefits between organic and paddy rice inorganic in the study area.

Organic fertilizers, such as compost and manure, promoted better soil structure and minimized the risk of water contamination compared to synthetic fertilizers. Sahoo *et al.* (2024) reported that while organic fertilizers led to lower immediate yields compared to inorganic fertilizers, they contributed to the sustainability of rice farming by improving long-term soil fertility and microbial activity. The study showed that over multiple cropping seasons, organic fertilizer-treated plots had better soil health indicators compared to inorganic-treated plots.

Saha *et al.* (2018) conducted a study with a control group (no fertilizer) and found that rice yield in the control group was significantly lower than in plots receiving either organic or inorganic fertilizers. The control group showed a 50% reduction in rice yield compared to inorganic fertilizer-treated plots and a 35% reduction compared to organic fertilizer-treated plots. Yadav *et al.* (2019) was used to compare the effects of organic and inorganic fertilizers on soil health. Their study indicated that, without fertilizer application, soil nutrients such as nitrogen, phosphorus, and potassium were much lower than in treated plots.

Impact of Fertilizers on Rice Yield Enhancement and Agronomic Efficiency

Inorganic fertilizers, particularly those containing nitrogen (N), phosphorus (P), and potassium (K), have been central to the Green Revolution and continue to be a primary input in modern rice agriculture. Their ability to supply nutrients in precise, soluble forms provides a rapid boost to crop growth and yield. However, increasing concerns over soil degradation, environmental pollution, and economic sustainability have prompted deeper research into their long-term effects. This discussion outlines recent findings on the agronomic, environmental, and economic implications of inorganic fertilizer use in rice systems.

Inorganic fertilizers are highly effective at improving rice yields due to their immediate nutrient availability. Nitrogen, in particular, enhances vegetative growth and grain filling, while phosphorus improves root development and potassium strengthens plant resilience. Recent studies confirm that proper application of NPK fertilizers can raise rice yields by 30–60% compared to unfertilized fields.

A study by Tanaka et al. (2023) found that nitrogen applied at 120 kg/ha increased grain yield by 58% over the control. Furthermore, balanced application of NPK outperformed nitrogen-only treatments, highlighting the need for nutrient synergy in rice cultivation. However, the efficiency of nutrient use is influenced by timing, method of application, and irrigation management. Technologies like deep placement and fertigation are being promoted to improve fertilizer use efficiency (FUE).

Nutrient Losses and Environmental Consequences

Despite their benefits, inorganic fertilizers are notorious for their inefficiencies. In flooded rice paddies, nitrogen losses can be as high as 50% due to volatilization, leaching, and denitrification. These losses not only reduce fertilizer efficiency but also contribute to serious environmental issues.

Iqbal et al. (2024) reported that conventional broadcast application of urea resulted in a 46% nitrogen loss, contributing significantly to ammonia emissions and nitrate contamination of groundwater. Similarly, Zhang et al. (2023) found that nitrogen fertilizers accounted for 40% of agricultural nitrous oxide (N_2O) emissions in Asia, a potent greenhouse gas with a global warming potential 300 times that of CO_2. These findings emphasize the need for improved nitrogen management strategies, including split applications, use of inhibitors, and precision agriculture tools.

Soil Health Implications

Long-term use of inorganic fertilizers can degrade soil health by reducing organic matter, increasing soil acidity, and disrupting microbial diversity. While they provide nutrients, they do not contribute to soil structure or biological activity, unlike organic amendments.

Liu et al. (2022) conducted a 20-year field study showing that exclusive use of chemical fertilizers decreased soil organic carbon by 25% and significantly reduced beneficial microbial populations. This decline in biological health can affect the soil's natural nutrient cycling capacity and long-term productivity. Acidification due to ammonium-based fertilizers also leads to nutrient imbalances, particularly micronutrient deficiencies in iron, zinc, and manganese. This necessitates periodic soil testing and liming in intensive rice systems.

Economic Impact and Sustainability Practices

Inorganic fertilizers are attractive to farmers due to their immediate results. However, their rising cost and diminishing returns in high-input systems pose challenges to economic sustainability. This is particularly evident among smallholder farmers, who often lack access to credit or knowledge of efficient fertilizer use.

Rahul & Devi (2024) found that while fertilizer application increased gross yields, net profits declined in regions with fertilizer overuse due to higher input costs and declining marginal yield gains. Fertilizer subsidies, while helpful, sometimes lead to excessive use and inefficiency.

To address this, governments and extension agencies are promoting site-specific nutrient management (SSNM) and soil health cards to guide optimal fertilizer use based on soil testing.

The drawbacks of exclusive reliance on inorganic fertilizers have led to the emergence of Integrated Nutrient Management (INM), which combines chemical fertilizers with organic inputs like compost, green manure, and bio-fertilizers. This approach improves nutrient cycling, enhances soil health, and maintains yield sustainability.

Singh et al. (2023) showed that INM practices improved soil organic carbon, microbial activity, and rice yields comparable to high-input chemical systems. Moreover, INM reduced the environmental footprint of rice farming by lowering GHG emissions and improving nutrient use efficiency. Adoption of INM can also reduce the dependency on costly chemical inputs, making farming more resilient to market fluctuations and climate stress.

Methodology

This chapter focusses on the source of data used and the methods used for the analysis. To assess the effects of site, variety, and fertilizer application on crop performance, a multivariate analysis of variance (MANOVA) was conducted. The following steps outline the methodology:

Study Area and Experimental Layout

The research was conducted at the research unit of National Cereal Research Institute (NCRI) Badeggi, in Niger state during the 2022-2023 farming season. The experimental field was plowed with a chisel plow and basins were prepared. Each plot size was $16m^2$ and was separated from each other by 1m space. The soils at Badeggi site are sandy loam with bulk density of $1.489gm^3$. The relative humidity at dry and raining season ranges between 75 – 85%. Annual rainfall at the site ranges between 1,200 – 1,400mm and mean temperature of between 23^{0c} – $33^{0c.}$.These research was conducted in a Randomize Block Design with three replication and 36- level of rice, the plant height was measured in 4, 6, 8 and 10 weeks, and the tillering height was also measured at 4,6,8 and 10 weeks.

Experimental Treatments

Treatments consisted of factors: Site (3 levels), Variety (4 levels), Fertilizer (3 levels), Dependent Variables: Plant height, Tiller height, Grain yield.

Each factor was fully crossed, resulting in 36 unique treatment combinations across replications.

Data Measurement

Measurements were taken at 4, 6, 8, and 10 weeks for growth parameters. Grain yield was measured at harvest. Plant height and tiller height were averaged across ten plants per plot. The data for this study was a secondary data obtain from an experiment conducted by the research unit of the National Cereal Research Institute Badeggi in Niger state. Data on plant height is collected by measuring the distance from the base of the plant to the tip of the main head (panicle). Taking an average height of 10 plants. Data on growth parameters of rice were collected from Randomize complete block design (RCBD) with three replications. Several agronomic traits were measured for each treatment combination, including but not limited to: plant height, Tiller height, and final yield. The data was collected at various growth stages to capture the temporal variation in response to the treatments.

The measurements were recorded for each variety, at each site, and under each fertilizer treatment.

The following hypotheses are proposed to be tested in this work.

- H_{o1}: there is no significant effect of planting site on rice plant height, tiller height and grain yield.
- H_{o2}: there is no significant effect of variety on rice plant height, tiller height and grain yield.
- H_{o3}: there is no significant effect of fertilizer type on rice plant height, tiller height and grain yield.
- H_{o4}: there is no significant effect of each of *site x variety*, *site x fertilizer type*, and *variety x fertilizer type* interactions on rice plant height, tiller height and grain yield.
- H_{o5}: there is no significant effect of *site x variety x fertilizer type* interaction on rice plant height, tiller height and grain yield.

Multivariate Statistical Approach

MANOVA was conducted using STATA and MINITAB software. The model included main effects and all two-way and three-way interactions. Significance was tested using Wilks' Lambda, Pillai's Trace, Hotelling's Trace, and Roy's Root. The model assumptions normality, homogeneity of covariance matrices, and sample size equality were verified before analysis. The 3-way MANOVA model below is used to describe the collected data used in this work.

$$y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + (\alpha\beta\gamma)_{ijk} + \epsilon_{ijkl} \qquad (2.1)$$

where

y_{ijkl} denotes the observed value of the response variable for ith level of site factor (factor A), jth level of variety factor (factor B), kth level of fertilizer factor (factor C) in the lth replicate.

μ is the overall mean.

α_i is the effect of the ith level of the site factor.

β_j is the effect of the jth level of the variety factor.

γ_k is the effect of the kth level of the fertilizer factor.

$(\alpha\beta)_{ij}, (\alpha\gamma)_{ik}, (\beta\gamma)_{jk}$ and $(\alpha\beta\gamma)_{ijk}$ are the respective interaction terms.

ϵ_{ijkl} is the random error term.

Results

Multivariate Tests.

The results of the multivariate analysis of variance (MANOVA) test are presented in Table 4.1 and those of the univariate tests are presented in table 4.2.

Table 3.1a: Multivariate Tests

Effect	Value	F	Hypothesis df	Error df	Sig.
Intercept					
pillai's Trace					
Wilks'Lambda	0.988	1882.535[b]	3	70	0.000
Hotelling's Trace	0.012	1882.535[b]	3	70	0.000
Roy's largest Root	80.68	1882.535[b]	3	70	0.000
	80.68	1882.535[b]	3	70	0.000
Site					
pillai's Trace	0.503	7.962	6	142	0.000
Wilks'Lambda	0.506	9.473[b]	6	140	0.000
Hotelling's Trace	0.958	11.022	6	138	0.000
Roy's Largest Root					
	0.939	22.218[c]	3	71	0.000
Variety					
Pillai's Trace	0.509	4.906	9	216	0.000
Wilks' lambda	0.502	6.198	9	170.512	0.000

Effect	Value	F	Hypothesis df	Error df	Sig.
Hotelling's Trace	0.969	7.391	9	206	0.000
Roy' Largest Root					
	0.945	22.675[c]	3	72	0.000
Fertilizer					
Pillai's Trace	0.199	2.62	6	142	0.019
Wilks' Lambda	0.802	2.719[b]	6	140	0.016
Hotelling's Trace	0.245	2.816	6	138	0.013
Roy's Largest Root					
	0.237	5.615[c]	3	71	0.002

Table 3.1b: Multivariate Tests

Effect	Value	F	Hypothesis df	Error df	Sig.
Site *Fertilizer					
Pillai's Trace	0.09	0.558	12	216	0.874
Wilks' Lambda	0.911	0.553	12	185.494	0.877
Hotelling's Trace	0.096	0.548	12	206	0.881
Roy's Largest Root	0.074	1.332[c]	4	72	0.266
Variety *Fertilizer					
Pillai's Trace	0.287	1.27	18	216	0.21
Wilks' Lambda	0.727	1.318	18	198.475	0.179
Hotelling's Trace	0.358	1.365	18	206	0.152
Roy's Larges Root	0.296	3.554[c]	6	72	0.004
Site*Variety					
Pillai's Trace	0.463	2.189	18	216	0.004
Wilks' Lambda	0.596	2.215	18	198.475	0.004
Hotelling's Trace	0.584	2.228	18	206	0.004
Roy's Largest Root	0.372	4.463[c]	6	72	0.001
Site*Variety*Fertilizer					
Pillai's Trace	0.35	0.791	36	216	0.797
Wilks' Lambda	0.681	0.8	36	207.55	0.785
Hotelling's Trace	0.423	0.808	36	206	0.774
Roy's Largest Root	0.286	1.717[c]	12	72	0.081

a. Design: Intercept + Site + Variety + Fertilizer + Site *Fertilizer + Variety * Fertilizer +Site *Variety + Site * Variety * Fertilizer
b. Exact Statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.

MANOVA Results Summary:

Site: Significant multivariate effect (Wilks' λ = 0.506, F = 9.473, $p < 0.001$).
Variety: Highly significant (Wilks' λ = 0.502, F = 6.198, $p < 0.001$).
Fertilizer: Moderate but significant (Wilks' λ = 0.802, F = 2.719, p = 0.016).
Interaction Effects:
Site × Variety: Significant (Wilks' λ = 0.596, p = 0.004).
Site × Fertilizer: Not significant (p = 0.877).
Site × Variety × Fertilizer: Not significant (p = 0.785).

Discussion

The multivariate analysis results indicate significant findings across various effects and interactions related to Site, Variety, Fertilizer, and their combinations. The intercept terms for all tests (Pillai's Trace, Wilks' Lambda, Hotelling's Trace, and Roy's Largest Root) were highly significant ($p < 0.001$), confirming that the combined dependent variables differ significantly from zero. For the main effects, Site and Variety showed strong significance in all test statistics, with p-values less than 0.001, indicating that both environmental factors (Site) and genetic differences (Variety) significantly influenced the growth and yield of rice. Fertilizer also demonstrated significant effects, though weaker than Site and Variety, with p-values ranging from 0.013 to 0.019 across various tests. Notably, the interaction between Site and Fertilizer, as well as Variety and Fertilizer, showed no significant effect ($p > 0.05$), suggesting that these factors do not interact to influence the dependent variables in a meaningful way. However, the interaction between Variety and Fertilizer approached significance (p = 0.004 for Roy's Largest Root), suggesting potential variety-specific responses to fertilizer. The interaction between Site and Variety was highly significant (p = 0.004), indicating that the effect of rice variety on growth and yield was dependent on the site of cultivation. Conversely, the three-way interaction between Site, Variety, and Fertilizer was not significant ($p > 0.05$), indicating no combined effect from these factors on the dependent variables. Overall, these results highlight the primary importance of Site and Variety in influencing rice growth, with a weaker but notable influence of Fertilizer and some potential for variety-specific fertilizer responses. This is consistent with the work of Cheng et al. (2014) and Liu et al. (2017), who highlighted the importance of multivariate frameworks in studying soil–plant interactions and crop response. There is a lack of comprehensive studies using **multivariate analysis of variance (MANOVA)** to assess how combinations of these factors jointly influence rice performance. This study seeks to fill that gap by applying MANOVA to investigate how site, variety, and fertilizer interactively affect multiple growth indicators, thereby offering a more holistic understanding for optimizing rice production strategies.

Conclusion

The multivariate analysis confirmed that site and variety are the dominant factors influencing rice plant height, tiller height, and grain yield. Fertilizer application, though statistically significant, exerted a weaker multivariate influence. The significant site × variety interaction further indicates that optimal rice productivity is achieved through careful matching of varieties to specific environmental conditions. MANOVA proved to be a valuable statistical approach for capturing these complex multivariate relationships.

Recommendations

Researchers and agronomists should incorporate MANOVA in agronomic studies to evaluate multiple correlated traits simultaneously.

Site selection and variety deployment should be co-optimized to maximize performance.

National rice improvement programs should include multivariate performance benchmarks in variety selection protocols.

References

Andriatmoko, N. D. (2020). Analysis of production factor efficiency in organic rice farming (Oryza sativa): A case in Sukorejo Village, Sambirejo Sub-district, Sragen District. Habitat, 31(1), 1–10.

Dollison, M. D. (2023). Comparative yield performance of rice production under organic and inorganic fertilizer application. International Journal of Multidisciplinary: Applied Business and Education Research, 4(7), 2173–2179. https://doi.org/10.11594/ijmaber.04.07.22

Emeana, E. M., Trenchard, L., Dehnen-Schmutz, K., & Shaikh, S. (2019). Evaluating the role of public agricultural extension and advisory services in promoting agroecology transition in Southeast Nigeria. Agroecology and Sustainable Food Systems, 43(2), 123–144. https://doi.org/10.1080/21683565.2018.1496071

Iqbal, A., Liu, C., & Sun, G. (2024). Nitrogen fertilizer losses and mitigation strategies in flooded rice paddies: A review. Agriculture, Ecosystems & Environment, 359, 108572. https://doi.org/10.1016/j.agee.2023.108572

Liu, Y., Zhang, L., Wang, H., & Chen, X. (2022). Long-term impacts of chemical fertilizers on soil carbon dynamics and microbial diversity in rice systems. Soil Biology and Biochemistry, 165, 108525. https://doi.org/10.1016/j.soilbio.2021.108525

Priya, R., & Singh, S. (2024). Factors influencing the adoption of sustainable agricultural practices: A systematic literature review and lessons learned for India. Forum for Social Economics, Advance online publication. https://doi.org/10.1080/07360932.2024.2345678

Rahul, V., & Devi, R. (2024). Economic implications of fertilizer overuse in smallholder rice systems: A case study from South Asia. Journal of Agricultural Economics, 75(2), 315–330. https://doi.org/10.1111/1477-9552.12456

Saha, S., Roy, P., & Das, D. (2018). Effect of organic and inorganic fertilizers on rice yield and soil fertility. International Journal of Current Microbiology and Applied Sciences, 7(8), 2488–2496. https://doi.org/10.20546/ijcmas.2018.708.263

Sahoo, P., Singh, T., Saini, K. S., & Kaur, J. (2024). Effect of residue incorporation and integrated nutrient management on productivity of spring maize in rice-based systems. Indian Journal of Agricultural Sciences, 94(1), 80–85.

Singh, A., Yadav, R., & Kumar, S. (2023). Integrated nutrient management practices improve rice productivity, soil organic carbon, and reduce environmental footprint. Nutrient Cycling in Agroecosystems, 127(1), 45–60. https://doi.org/10.1007/s10705-023-10267-1

Tanaka, H., Kobayashi, T., & Yamamoto, M. (2023). Nitrogen management and yield performance in irrigated rice: Field evidence from Japan. Field Crops Research, 294, 108868. https://doi.org/10.1016/j.fcr.2023.108868

Verburg, R. W., Verberne, E., & Negro, S. O. (2022). Accelerating the transition towards sustainable agriculture: The case of organic dairy farming in the Netherlands. Agricultural Systems, 198, 103368. https://doi.org/10.1016/j.agsy.2021.103368

Yadav, S., Lal, M., Naresh, R., Yadav, R., Yadav, A. K., Yadav, K., Kumar, R., Chandra, M. S., & Rajput, P. (2019). Effect of organic and inorganic nutrient sources on productivity, grain quality of rice and soil health in north-west IGP: A review. International Journal of Current Microbiology and Applied Sciences, 8(12), 2488–2514. https://doi.org/10.20546/ijcmas.2019.812.292

Zhou, Z., Zhang, S., Jiang, N., Xiu, W., Zhao, J., & Yang, D. (2022). Effects of organic fertilizer incorporation practices on crop yield, soil quality, and soil fauna feeding activity in the wheat–maize rotation system. Frontiers in Environmental Science, 10, 1058071. https://doi.org/10.3389/fenvs.2022.1058071

Zhang, X., Huang, Y., & Guo, J. (2023). Nitrous oxide emissions from rice paddies under intensive nitrogen fertilization in Asia. Science of the Total Environment, 869, 161748. https://doi.org/10.1016/j.scitotenv.2023.161748